CASE HISTORIES

Lining Prevents Biogenic Sulfide Corrosion In Wastewater Systems

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Faced with serious concrete deterioration from biogenic sulfide corrosion within collection systems, engineers and municipalities are extending the service life of wastewater conveyance structures with the use of 100% solids polyamine systems designed for hydrogen sulfide (H_2S) permeation resistance. This article explains how sewer interceptors, manholes, and lift stations were protected using fluid-applied linings.

Federal and municipal authorities are in general agreement that the nation's wastewater collection system infrastructure, including sewer interceptors (Figure 1), manholes (Figure 2), and lift stations (Figure 3), is deteriorating at an alarming rate. The U.S. Environmental Protection Agency (Washington, DC) has estimated that in the next 10 years, the United States will have to invest more than $11 billion to upgrade existing wastewater collection systems, more than $24 billion for new sewer construction, and nearly $50 billion to improve combined sewer overflow problems.[1]

Nationwide, there are approximately 800,000 miles (1,287,200 km) of sewer lines and 100,000 major pumping stations, according to the U.S. Government Accountability Office (Washington, DC).[2] The most widely used construction material in wastewater collection systems is concrete, which can deteriorate when exposed to biogenic sulfide corrosion. Corrosion damage can be particularly extensive in systems where large-diameter gravity sewers constructed at flat slopes discharge into the treatment facility. Since hydrogen sulfide (H_2S) gas is produced within the anaerobic slime layers that form on sewer pipes and related surfaces, these longer transport distances increase wastewater septicity and the dissolved H_2S concentrations.

The effect of biogenic sulfide corrosion on concrete is a reaction with the cement binder, causing the concrete to deteriorate. In wastewater environments, where H_2S levels can reach several hundred parts per million, the corresponding deterioration of unprotected concrete can exceed 1 in./y (25.4 mm/y), according to industry estimates. Research indicates that the older the pipe, the more likely it is to have corrosion damage and require replacement or rehabilitation.

Preventing Permeation

Among the rehabilitation methods used for concrete interceptors, manholes, and lift stations is 100% solids, high-build protective epoxy mortar or lining systems formulated for high permeability resistance to H_2S, sulfuric acid (H_2SO_4), and other wastewater gases. Permeability to corrosive substances is the most critical factor for these chemically resistant coatings, according to a recent survey of wastewater engineers, municipal managers, and contractors conducted by *Water Online.*[3]

A critical consideration for preventing permeation of these protective coatings is proper surface preparation of new and existing concrete following industry standards, such as NACE No. 6/SSPC-SP 13, "Surface Preparation of Concrete."[4] This joint standard includes a requirement for filling voids, bugholes, and other cavities in the concrete before a coating is applied (Figure 4). Otherwise, air trapped in these cavities can be released into or through the protective coating, creating pinholes and holidays. The escaping air is described as bughole-induced outgassing.[5]

Among the materials available for filling bugholes are epoxy-modified cementitious resurfacers, also known as epoxy-modified cements. These materials are applied to the concrete as a thin overlay at an approximate thickness of 1/16th in. (1.6 mm). The epoxy-polymer modification allows the cementitious resurfacer to be applied as a thin patch material, while increasing its density to make the mortar less susceptible to outgassing when topcoated.

A 100% solids epoxy protective coating system designed with exceptionally low H_2S permeability and H_2SO_4 resistance is available for existing and new collection system substrates (Figure 5). Trowel-applied epoxy mortars feature aggregate reinforcement, which makes the film coefficient of linear thermal expansion (CLTE) properties similar to those of concrete. This reduces the potential for cracking if exposed to thermal cycling and dissipates impact or abrasion.

Spray-applied, "neat" resinous epoxy systems offer enhanced permeation resistance, but do not have the same CLTE properties as coatings with aggregate or fiber reinforcement. These resinous

FIGURE 1

Typical 48-in. precast sewer interceptor lined with a 100% solids, fiber-reinforced polyamine epoxy for elevated H_2S resistance.

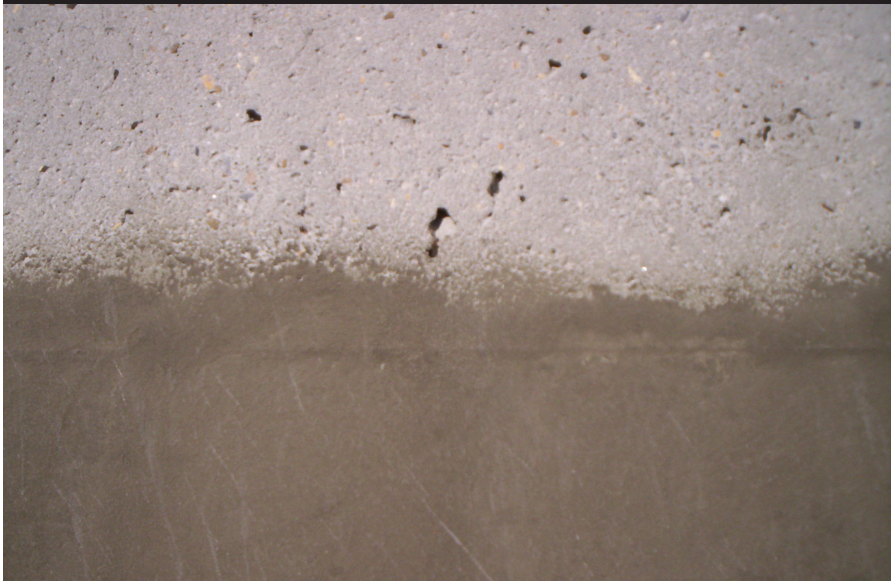
FIGURE 2

Precast manhole protected from biogenic sulfide corrosion using 100% solids, fiber-reinforced epoxy liner.

FIGURE 3

Finished appearance of a lift station restored with an epoxy coating thin overlay, then lined at 125 mils with a 100% solids epoxy mortar and 15 to 20 mils of a 100% solids epoxy glaze coat.

FIGURE 4



Typical cast-in-place concrete wall containing exposed voids and bugholes (upper half of photo) and application of a greenish-grey epoxy-modified cementitious thin overlay (lower half) to create a contiguous surface for coating.

epoxy liners have a greater propensity to crack if applied at thicknesses >100 mils, if exposed to extreme thermal cycling, or if submitted to impact and abrasion forces. For those applications where spray-applied systems are desired over epoxy mortars for productivity, but the severe environments warrant greater flexural and tensile strength, spray-applied fiber-reinforced epoxy systems are available for added impact and abrasion resistance. The fibers provide reinforcement and dissipate curing and impact stresses, while offering productivity advantages because of their spray application.

Renovating Concrete

Trowel-applied epoxy mortars lend themselves to rehabilitative projects where the substrate is highly eroded and a thicker film build is required to create a contiguous surface. Such a coating system was used in the Village of Lyons, New York, where biogenic sulfide corrosion caused serious damage to the concrete substrate in a lift station wet well.

The highly eroded surface was pressure-washed and abrasive-blasted before an epoxy-modified cementitious resurfacer was trowel-applied to patch the deep holes and resurface the damaged concrete. After the substrate was resurfaced, a two-component, 100% solids polyamine epoxy mortar was trowel-applied at 1/8-in. (3.2-mm) thickness and backrolled using a 1/4-in. (6.4-mm) nap roller to smooth and tighten the system. A 100% solids polyamine epoxy glaze coat was then roller-applied as the topcoat at 15.0 to 20.0 mils dry film thickness (DFT) to provide added permeation protection.

After one year, a follow-up inspection found the new system to be in excellent condition with, most importantly, no deterioration of the concrete. Traditional thin film and coal tar epoxy coatings have been observed blistering in field applications at 50 to 100 ppm H_2S after 12 to 16 months in service. These failures were attributed to inadequate resistance to permeation by wastewater gases.

New Construction

In the City of Mishawaka, Indiana, a biogenic sulfide corrosion-resistant epoxy system was specified for more than a mile

(1.6 km) of 48-in. (1.22-m) diameter concrete sewer pipe and connecting structures. The sewer pipe, manhole, and lift station project was part of the Mishawaka Wastewater Treatment Plant expansion to increase average design capacity from 12 to 20 million gal/day (45 to 76 million L/day) for continued growth in the community, and to cut annual combined sewer outflow volume in half.

The 48-in. diameter concrete pipe was fabricated in 10-ft (3-m) sections. Each section was specified to be abrasive-blasted before spray application of the fiber-reinforced modified polyamine epoxy lining. The coating was applied with a high-pressure, airless spray pump at 80.0 to 125.0 mils DFT. The total project required more than 1,600 sections of pipe and an estimated 2,500 to 3,000 gal (9,463 to 11,355 L) of coating material.

Manholes and lift stations were abrasive-blasted in accordance with NACE No. 6/SSPC-SP 13, ICRI-CSP5 to remove laitance and other contaminates and to provide a surface profile. An epoxy-modified cementitious resurfacer was trowel-applied as a 1/16-in. parge coat before spray-applying the epoxy liner. The specifying engineering firm for this project had used the same coating system in Indianapolis, having determined that it would be cheaper to coat these pipes than replace them because of corrosion.

FIGURE 5

Trowel application at 125 mils of a 100% solids epoxy mortar system designed for elevated H_2S permeation resistance.

Measuring Performance

To substantiate permeation performance in wastewater environments, the 100% solids epoxy systems underwent Severe Wastewater Analysis Testing (S.W.A.T.). Developed by Tnemec Co. (Kansas City, Missouri) in conjunction with leading engineers, municipal owners, and a state-of-the-art laboratory, this accelerated testing program simulates severe wastewater conditions and evaluates coating performance with regard to permeation resistance, chemical exposure, adhesion, substrate deterioration, and long-term performance.

One technique, widely used in the laboratory and field for determining coating performance and obtaining quantitative information on coating deterioration, is based on electrical resistance of the coating, which is referred to as impedance. The testing procedure applies electrochemical impedance spectroscopy (EIS) technology to evaluate the level of coating degradation after exposure to a severe wastewater environment.

Measuring the coating's resistance as impedance to an electrical current provides a correlation to its overall permeation performance. A coating in good condition resists permeation, or electrical current, as opposed to a coating that has degraded. The higher the resistance of a coating, the lower its permeability to H_2S, chemicals, ions, water, and gases.

In laboratory testing, EIS readings are taken before, during, and after coatings are exposed to a simulated severe wastewater environment. These readings easily detect if a coating is attacked or breached, as indicated by a decrease in the measured impedance. Results of this testing provide a correlation to real life failure in a wastewater environment. Other measurements include blistering, adhesion, and visual inspection.

Thicker film epoxy lining systems, such as the type used in the Village of Lyons and City of Mishawaka collection systems, demonstrate excellent impedance, no blistering, and maximal adhesion based on this testing procedure. In the same test, traditional coal tar and other thin film epoxy coatings demonstrated poor permeation resistance, delamination, and cracking.

Conclusions

H_2S gas concentrations have become more severe in the aerated vapor phase of sewer pipes, manhole chambers, and other wastewater system structures. This increase has caused greater H_2SO_4 generation by sulfur oxidizing bacteria present in the headspaces. The overall result has been elevated H_2S and other acid gas concentrations and more constant H_2SO_4 formation. These concentrations have reduced the life expectancy of thin film coatings from several years to a few months. Today's new generation of protective coatings offers a monolithic, seamless system that is cost-effective and provides excellent H_2S permeation resistance to thin film coatings.

References

1 EPA 816-R-02-020, "The Clean Water and Drinking Water Infrastructure Gap Analysis" (Washington, DC: U.S. Environmental Protection Agency, September 2002).

2 GAO-96-390, "Securing Wastewater Facilities" (Washington, DC: U.S. Government Accountability Office, May 1, 2000), p. 8.

3 "New Survey Shows Permeability a Critical Corrosion Factor," Water Online, November 7, 2006.

4 NACE No. 6/SSPC-SP 13, "Surface Preparation of Concrete" (Houston, TX: NACE International).

5 V. O'Dea, "Preventing Bughole Induced Outgassing," JPCL 24, 1 (2007): p. 86-88.

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