Long-Term Lift Station Rehabilitation at Jefferson Parish, Louisiana

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Municipalities in the United States are annually spending hundreds of millions of dollars to replace and to repair corroded concrete infrastructures in their wastewater collection systems. In addition, billions more dollars will be needed in the coming years to restore, replace, and upgrade existing facilities all across the United States. Structures such as wet wells, grit chambers, sewer lines, and aeration basins all experience severe corrosion. These problems are aggravated by the fact that corrosion protection was typically not incorporated into the initial structure installation. Replacement of these structures can cost three or more times as much as an in-situ rehabilitation. Beyond the initial capital cost, replacement of these structures may involve traffic interruption and construction problems with buildings, highways, and other facilities. The money saved by rehabilitating structures, rather than replacing them, can further be used to fund more extensive rehabilitation projects or other programs such as Inflow/Infiltration (I&I) projects.

Corrosion problems in municipal wastewater treatment systems are caused by quite different mechanisms than those corrosion problems typically found in industrial treatment systems. In industrial systems, corrosion attack is generally due to the direct aggression by chemicals and their reaction products, which are present in the various discharge streams being serviced by the system. In municipal wastewater systems, however, corrosion is caused by microbiological induced corrosion (MIC), not by discharged chemicals.

HISTORICAL CORROSION BELIEFS AND FACTS

Corrosion of concrete, steel and other materials of construction have long been a problem in the municipal wastewater collection and treatment industry. Some geographical areas experience significantly greater corrosion problems than others, however, no areas in the United Sates are exempt from the MIC corrosion process. The responsible authorities were slow to recognize the problem and researchers were incorrect, in their early assessments of the primary cause of wastewater corrosion. Consequently, proper remedial and preventative actions were slow to be adopted. The wastewater industry has long relied on the many industry standards that have specified the use of so-called sulfate-resistant concretes, based upon ASTM Type II Portland Cement. This reliance was based upon the mistaken belief that Type II Cement resists acid corrosion better than Type I Cement.

Also, the wastewater industry had operated upon the mistaken assumption that Hydrogen Sulfide (H_2S) was the primary causative agent in the corrosion process. It is now known that biogenically generated H_2S plays the initiating role in the actual corrosion mechanism; but, the overall contribution of H_2S to corrosion is actually quite small. H_2S does; however, play an extremely critical role in the facilitation of MIC.

It has been known, since before the turn of the 20th century, that concrete exposed to H_2S producing sewage does experience corrosion. It has also been known, since 1926, that Sulfuric Acid (H_2SO_4) was the corroding medium, not H_2S. What the researchers and other authorities did not understand was the operating mechanism used to convert H_2S to H_2SO_4. The wastewater industry now knows that the operative mechanism is microbial. Certain microbes respire H_2S and use it to chemically reduce the organic sulfates found in sewage. By this method, these microbes produce the energy needed to survive. The chemical reduction of sulfates oxidizes H_2S to H_2SO_4. The microbes involved are referred to as Sulfate Reducing Bacteria (SRB) and there are anaerobic and aerobic species that are usually involved in the process. Examples of aerobic microbes are the strains of Thiobacillus bacteria and the anaerobic strain is usually Desulfovibrio desulfuricans (D. desulfuricans). D. desulfuricans uses the iron in embedded reinforcement steel to catalyze the sulfate reduction.

CORROSION MECHANISM

The pH of new concrete will range from a pH of 12 to 13. Carbon dioxide (CO_2) and H_2S condense with water vapor to form weak acidic conditions. These condensates then react to form thionates and carbonates and to lower the pH below pH 11. From this point, there is a progressive growth of various microorganisms, including Thiobacilli bacteria (see Figure 1). Many of these microbes secrete acid waste products, including organic acids and H_2SO_4 acid. As the pH of the concrete is steadily lowered, the conditions become more favorable to the destructive Thiobacillus concretivorous bacteria, which will survive from pH > 7 to pH < 1, and the Thiobacillus thiooxidans bacteria, which will survive to a pH < 0.6.

CORROSION PROCESS

Very little data has been published on the corrosion rates of concrete in various corrosive environments. It is however, well established that sewage structures corrode in acidic media and these structures are unsuited for these exposures. There exists some common misconceptions regarding the requirements for concrete corrosion. Not surprisingly, the corrosion requirements do not significantly differ from those requirements for metallic corrosion. The degree of access to the concrete matrix, moisture, temperature, pressure, velocity of corrodent streams, time, media composition and concentration are all controlling factors. One of the common misconceptions encountered is that a high relative humidity is required for concrete to corrode. All that really is required is for the corrodent to be deposited as a liquid directly onto the concrete or for sufficient moisture to be present. This condition will allow for condensation of those species that are below their dew point. This level may be reached at as little as 0.1% atmospheric moisture. Once condensation occurs, there exists enough free moisture in the concrete to allow reactions to proceed autogenically. About 20% of the water mixed with the typical Portland Cement based concretes actually enters into the hydration reactions. The rest is “water of convenience,” which allows the mixture to be placed in its final location. This “water of convenience” remains trapped within the concrete matrix, available to dissolve, ionize and react. It is true that microbiologically influenced corrosion (MIC) in wastewater collection and treatment systems tends to be more aggressive in structures with higher atmospheric moisture. This fact, however, is due more to the formation of an environment favorable to rapid growth of bacteria, which includes appropriate moisture levels.

The acidic secretions from the Thiobacilli bacteria are liquids and are secreted directly onto the concrete. These liquids are subsequently held in place by a blanket of the other acid secreting microbes. The free lime (CaO) in Portland Cement will react quite readily with any concentration of sulfuric acid at all temperatures above the freezing point of the acid that is present.

Another misconception in the industry is that the primary source of corrosion is H_2S attack on concrete. While it is true that strong concentrations of H_2S will eventually corrode the Portland Cement matrix, the reaction is neither vigorous nor rapid and it is highly dependent on H_2S levels, temperature and time. In terms of competing reactions, the Portland - H_2SO_4 - H_2O, reaction will control vis a vis the Portland - H_2S - H_2O reaction, to the point that the latter will be unimportant, except for its major role in the initial acidification of the substrate. Of course, H_2S concentration also directly influences the rate of growth of the Thiobacillus bacteria, and is thus critical to the overall process.

A widely cited study by C. D. Parker on the MIC process dates back to 1951. For one strain of Thiobacillus bacteria – Concretivorous - Parker reports the effect of temperature on relative rates of H_2SO_4 formation. As expected, the metabolic process is accelerated as temperatures rise, showing a peak at $\approx$30°C (86°F). The acid concentrations and volumes are sufficient to destroy a large quantity of concrete, since one part of H_2SO_4 by weight will react with and destroy 2 1/2 parts of Portland Cement, based on stoichiometric ratios. Estimates of the biogenic H_2SO_4 concentration ranges as high as 43% H_2SO_4, by weight.

Application of loads such as bending moments and tensile stresses accelerates the corrosion rate by weakening and rupturing the already brittle bonds. As these bonds deteriorate, corrosion of the reinforcing steel further aggravates the corrosion problem by destroying the reinforcement and by inducing additional stresses on the concrete due to the internal formation of iron sulfates. These iron sulfates then expand to a volume several times that of the original steel and the swelling thus produced contributes to spalling of the concrete.

PREVENTION TECHNIQUES

Many existing wastewater systems do not employ corrosion protection of any sort for their concrete structures. For those municipalities that have performed preventative maintenance, the degree of success has been widely variant. Thin film coatings and surface treatments have generally not worked well. Thicker films of resin-based coatings such as urethanes, epoxies, vinylesters and others generally work very well when properly formulated and utilized. The drawbacks of thinner film coatings are a tendency to fail from negative side pressure due to the hydrostatic loads from groundwater. The hydrostatic pressure may cause thin films and some improperly formulated and applied systems to separate from the substrate.

CASE HISTORY: LIFT STATION REHAB IN LOUISIANA

Back in 1988 a Parish near New Orleans, LA faced major corrosion problems within pump stations, manholes, and lift stations. Several structures of 1970’s vintage had deteriorated severely because common practice at the time of installation included no protective barrier. The Parish engineer sought to mitigate the corrosion in order to prolong the life of the infrastructure. The first unit repaired, a lift station, demonstrates a dramatic example of how restoration can occur.

The concrete lift station, placed into service in 1972, measured 8 ft. x 3 ft. x 23 ft. Inside, two Force Mains (measuring 8” dia. and 10” dia.) and two Gravity Mains discharged into the Lift Station. After approximately fifteen years of such high duty service consisting of turbulent flow, abrasion and chemical attack due to MIC, it wasn’t surprising that extensive corrosion occurred. Worn aggregate, exposed reinforcing steel and severely spalled concrete were present throughout the structure. (see Figures 2, 3, 4).

When the Parish Department of Sewage decided to rehabilitate this Lift Station, they wanted to ensure that a thorough and a long-lasting job was performed to justify the rehabilitation expenses over a full replacement project. As a result, one of their primary objectives was to find a lining material that would protect refurbished concrete from chemical attack resulting from MIC. Moreover, they needed a product that could be applied quickly, and which would cure in a damp environment. Minimal downtime was critical to this project.

To meet these project requirements, the Parish engineer partnered with Meyer Engineering of Metairie, LA. The specified polymer liner was one developed in 1986 and brought to the wastewater market by Sauereisen, Inc of Pittsburgh, PA. The Sauereisen corrosion-resistant system included a fast-setting structural concrete to rehabilitate the concrete substrate and a trowel-applied protective polymer lining to prevent corrosion.

This 100% solids, aggregate-filled epoxy material, named SewerGard 210, was developed specifically to protect municipal wastewater treatment facilities from chemical attack and physical abuse. This material is still used successfully by the Wastewater Industry. The engineers chose SewerGard because it offered significant advantages over all the systems available at the time. Advantages such as:

- Resistance to corrosive conditions common to the municipal wastewater treatment industry.
- The selected system did not require a primer, permitting rapid installation of the lining once the surface preparation of the cement was complete.
- The lining was particularly suited to Louisiana’s high water table and humid environments, as it utilizes a specially developed resin formula, which enables the lining to cure on a moist surface in a damp environment and resist water infiltration.
- Strong bonding properties allow the lining to withstand the high duty service experienced at this Lift Station.

Sauereisen’s pre-qualified applicator for the project was Slidell, LA contractor Python Construction. Extensive preparation was performed on the concrete surface of the Lift Station. This preparation utilized typical techniques that included hydroblast equipment and air hammers to remove loose, weak, chemically attacked concrete and contaminants while the sewage was diverted, during the installation of new pumping equipment.

Once the surface preparation was complete, a fast-setting, cement-based underlayment was applied to restore structural integrity of the concrete and to provide a uniform surface for application of the corrosion-resistant lining. The selection of the proper underlayment is critical, as many substrate repair materials will tend to soften and re-emulsify in immersion conditions. The underlayment must also be compatible with the corrosion-resistant lining in order to provide a strong firmly bonded monolithic structure.

The corrosion-resistant lining was then applied to a 1/8-inch thickness with a single pass of a trowel. The surface was rolled with an 8-inch short-nap roller, which provided a uniform monolithic surface, free of pinholes, laminations and irregularities. The total application time, including surface preparation, was three days, and the lift station was returned to service within 24-hours after installation of the corrosion-resistant lining. (See Figure 5)

As a Quality Assurance measure, the lining was then spark tested (see Figure 6). High Voltage Spark Testing reveals any type of defect in the lining, many of which are not visible to the naked eye. Left unrepaired, these defects would allow water, sewage, bacteria and other corrodents to undercut the lining, leading to premature failure. The installation contractor easily repaired the identified areas and then retested the repaired areas. This testing process ensured a pinhole-free lining, which translated to optimum performance of the lining.

After almost fifteen years of prolonged service life, the municipality and Sauereisen technical personnel jointly inspected the lining in March 2002. In the ensuing years since 1988, the demanding service of this Lift Station had actually increased because of considerable development within the Parish. Consequently, expectations were that the structure could be in need of at least some degree of maintenance once again.

The epoxy lining, however, has been able to withstand these higher service levels. In an environment where cement loss due to corrosion typically measures 1/8 to 3/4 inch per year, the epoxy product has shown no signs of chemical attack or erosion. It is in excellent condition and firmly bonded to the substrate. No blisters, spalling or cracks have been observed and no chemical attack is present. (see Figure 7).

Many other similar installations, rehabilitated with this system, have shown the same dramatic results. The combination of a 100% solids resin system applied at a high-film thickness has proven itself to provide maintenance-free performance. The combination of high-solids and substantial film thickness allows the lining to withstand the I/I ground water forces and results in a lining with extremely low permeability, enhancing corrosion resistance.

CONCLUSION

Microbiologically Influenced Corrosion (MIC) is a prime cause of deterioration of concrete structures in the wastewater collection and treatment industry. The industry has long relied on the fact that many industry standards have specified the use of so-called sulfate resistant cements to make pipelines and appurtenances. The mistaken belief is that these concretes resist acid corrosion better than ordinary Type I cement.

The industry also incorrectly assumed, until quite recently, that biogenically generated hydrogen sulfide (H_2S) was the causative agent in the corrosion process. It is now known that H_2S plays an initiating role but its overall contribution to corrosion is quite small.

It has been known since the turn of the last century that concrete exposed to H_2S producing sewage experienced corrosion. It was even known since 1926 that sulfuric acid (H_2SO_4) was the corroding medium, not H_2S. What was not understood was the operating mechanism for oxidizing H_2S to H_2SO_4. The Wastewater Industry now knows that certain microbes will respire H_2S and use it to convert, by chemical reduction, organic sulfates found in the sewage to energy. This class of bacteria is often referred to as Sulfate Reducing Bacteria (SRB).

Factors critical to the long term performances of any lining system in the MIC environments includes such obvious factors as their effect on flow, abrasion, impact resistance, chemical resistance and permeability. The lining must not provide a growth platform for microbes.

The operating experience in Louisiana, and at many other locations, provides convincing evidence that a properly designed, applied and cured system will fully protect concrete against MIC.

The documented Lift Station represented a challenge to all several parties. By choosing the appropriate materials and rehabilitation methods, municipalities can save considerable funding and avoid the additional inconvenience required by complete structure replacement.

There are instances where concrete in wastewater service may be beyond repair, with replacement as the only option. In most cases, however, the proper materials, application methods and Quality Assurance measures make long-term rehabilitation projects not only feasible, but also practical.

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Figure 1. Environmental conditions promoting *Thiobacilli* growth.

Parameter	Thiobacillus concretivorous	Thiobacillus thiooxidans	Thiobacillus thioparus
Metabolic process	Oxidizes thiosulfates, elemental sulfur, sulfides	Oxidizes thiosulfates, elemental sulfur, sulfides	Oxidizes thiosulfate to sulfur and sulfate, not sulfide
pH			
Initial	7 to 8	7 to 8	7 to 8
Optimum Growth	2 to 4	>0.6	4 to 5
Slow Growth	<1	>5	>9, <5
Temperature			
Optimum Growth	50° to 75°F and 85° to 98.6°F	50° to 75°F and 85° to 98.6°F	50° to 75°F and 85° to 98.6°F
Slow Growth	75° to 85°F	75° to 85°F	75° to 85°F
Destroyed	Above 130°F	Above 130°F	Above 130°F

Figure 2. Lift Station Prior to Rehabilitation.

Figure 3. Lift Station Prior to Rehabilitation.

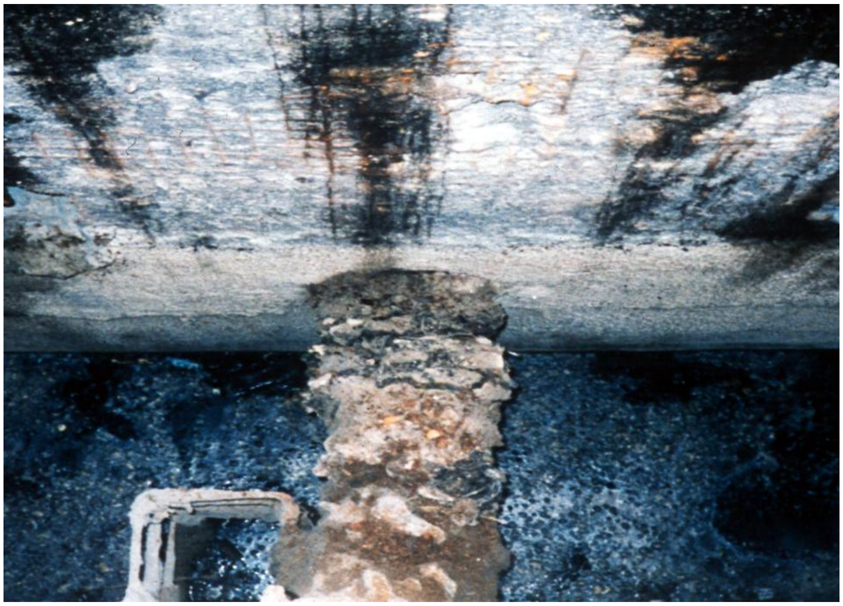

Figure 4. Lift Station Prior to Rehabilitation.

Figure 5. Rehabilitated Lift Station.

Figure 6. Typical Spark Testing Unit.

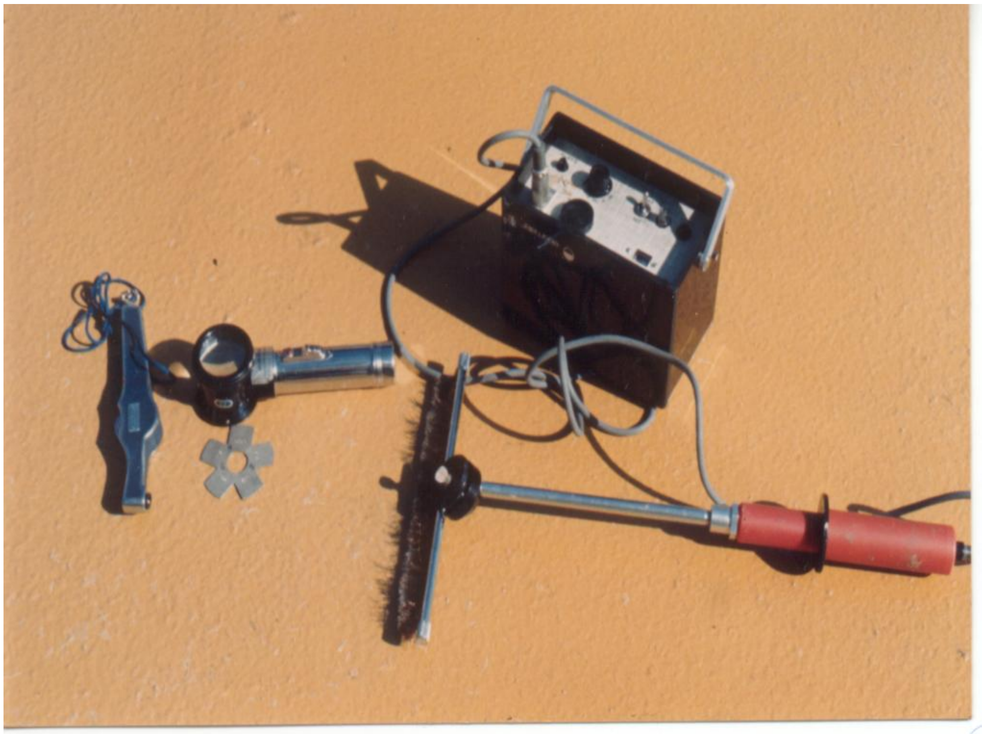

Figure 7. Lift Station in 2002.