Preventing Sewer Corrosion

Precasters take biology lessons to increase the life of concrete sewer systems.

By Paul Ramsburg

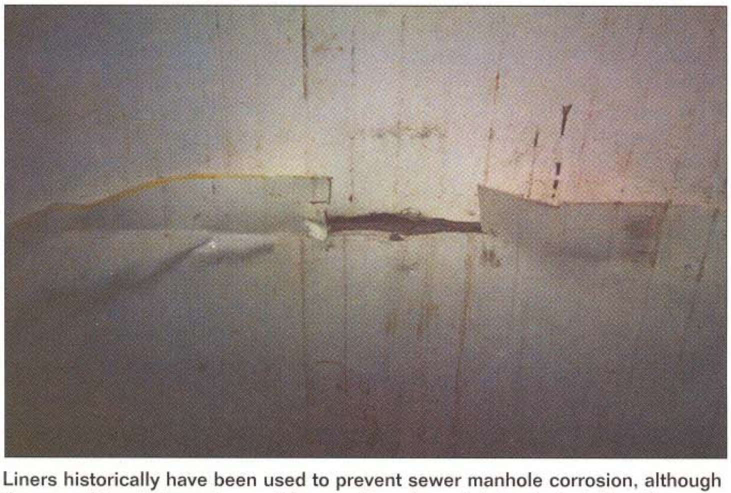
About 40% of the more than 20,000 wastewater systems in the United States are concrete. Corrosion severely compromises the structural integrity of these concrete components, costing millions in repairs.

Six decades after C.D. Parker discovered Microbial Induced Corrosion (MIC), many continue to incorrectly refer to the deterioration of sewer pipe as "a corrosive gas problem." But the real culprit for concrete is MIC, a process by which sulfuric acid is produced in sewer systems when hydrogen sulfide gas and *Thiobacillus* bacteria interact.

Anaerobic (non-air breathing) bacteria form in raw sewage and naturally produce hydrogen sulfide gas (H_2S) in sewer effluent. Factors contributing to rapid bacterial growth are temperature, retention time, high biological oxygen demand levels, and turbulence.

The more turbulent the effluent, the more hydrogen sulfide is released. This is most common at lift stations and manholes. This gas collects above the flow line where it combines with carbon dioxide (CO_2). Both of these "acid" gases produce a mild, weak acid solution when they dissolve into the sewer's moist environment.

The CO_2 produces carbonic acid, and the H_2S produces thiosulfuric and polyphonic acid. Both combine with the calcium hydroxide in the concrete to reduce the pH of the surface. But don't blame these mild acids for sewer line corrosion. As soon as the pH of the concrete falls from its initial levels of pH 11 or pH 12 to around pH 9, biological colonization



Liners historically have been used to prevent sewer manhole corrosion, although they can delaminate and wear thin over time. Any mistakes in installing them may render the liner useless.

Coatings and liners both can be eliminated by using anti-microbial admixtures. This eliminates not only the risk associated with human error during installation, but the complex and lengthy installation process altogether. The admixture solution typically means a lower "in-the-ground" cost for the manhole.

of *Thiobacillus* bacteria will occur. The countdown to serious corrosion and collapse begins at this point.

Thiobacillus bacteria have the unique ability to convert hydrogen sulfide gas into sulfuric acid (H_2SO_4) in the presence of oxygen. Different species of *Thiobacillus* colonize the concrete surface above the wastewater flows, reduce the pH, and die out, leaving the acid production to the next more aggressive species. The pH of the concrete changes from alkaline to very acidic. One such species is *Thiobacillus thiooxidans,* which is known to grow well in the laboratory while exposed to a 7% solution of sulfuric acid. This is equivalent to a pH of 0.5.

The sulfuric acid volumes at this level attack the concrete matrix. Although the reaction products are complex and form many different compounds, the primary product of decomposition by sulfuric acid is calcium sulfate ($CaSO_4$), or gypsum. This is visible as a pasty white mass above the wastewater line in sewer structures. Depending on the conditions of individual systems, this process may take years or just a few months.

TRADITIONAL CORROSION CONTROL

One method used to prevent corrosion of concrete sewer systems is a continuous or regular dosage of chemicals—potassium permanganate, chloride, and oxygen—injected directly into the raw sewage to reduce the original gases. But these are expensive and temporary fixes, at best.

Another method is protective coatings, which work well until you factor in human error. Experience shows coatings delaminate over time because of improper preparation of the concrete surface, or inadequate and improper application in the field.

Anti-microbial concrete has proven itself repeatedly in many years of successful testing.

Thiobacillus bacteria can penetrate inadequate coatings, live happily on the concrete surface beneath the coating, and further destroy the bond of the coating to the concrete. Liners too often delaminate from the walls of sewer structures or erode, forming an area that requires costly repair.

A NEW SOLUTION

The ideal method to reduce this type of MIC would be to permanently affect the bacterial cell growth, or the pH of the concrete, such that the bacteria no longer could grow and convert H_2S gas to H_2SO_4. This thought led to anti-microbial agents.

In 1993, an anti-microbial material was introduced to the concrete market that was integrated into a polypropylene fiber, which in turn could be introduced into concrete. But the anti-microbial effect was only on the fiber and not the entire mass of concrete. Testing showed this system was not capable of affecting *Thiobacillus* cell growth.

Three years later, a material was introduced that could be mixed directly into concrete. This anti-microbial agent resulted in a 100% reduction of *Thiobacillus* bacteria on and in concrete, and has maintained the 100% reduction.

This anti-microbial agent is a water-stabilized Silicone Quaternary Ammonium Salt (3-trimethoxysilypropyldimethyl-octadecylamine ammonium chloride) that provides effective anti-microbial properties when added to a concrete admixture. This material does not leech out; it becomes molecularly bonded to the cement particles, becoming an integral part of the concrete matrix.

It's safe for animals and humans, but creates a hostile environment for single-cell microbes. There is a U.S. Environmental Protection Agency registration number for anti-microbial admixtures for concrete (Reg.

Microbial Induced Corrosion at a Glance

1. An anaerobic bacterium in sewage produces hydrogen sulfide gas.
2. Turbulence from force mains, drop manholes, and pump stations allow the hydrogen sulfide gas to release into the atmosphere in pipes and manholes.
3. Sulfide gas is converted into sulfuric acid by the aerobic *Thiobacillus* bacteria that grow on the concrete surfaces above the wastewater flow.
4. Sulfuric acid produced by *Thiobacillus* quickly corrodes the concrete, resulting in severe structural damage to the pipe and manholes.

No. 70871-12). Because this material is mixed into the concrete, it cannot wash off, chip off, peel, delaminate, or pin hole.

POSITIVE RESULTS

Anti-microbial concrete has proven itself repeatedly in more than six years of successful field testing, with results provided by several bio-labs. Specimens are tested using modified ASTM G21-96 and G22-96 test methods (determining resistance to bacteria and fungus), as well as the American Association of Textile Chemists and Colorists test method 100-1993 to determine if bacteria could colonize on concrete containing this anti-microbial agent.

Oldcastle-Rotondo Precast's Fredericksburg, Va., facility began an extensive testing program early in 2003 to determine if this material is suitable for precast concrete production. Two self-consolidating concrete mix designs were used in the study with five varying dosage rates of anti-microbial agent.

There were no significant differences in plastic properties between mix designs noted during this testing. Nor was the consistency of test results affected by the addition of the agent. The same holds true for strength development, absorption (ASTM C-642), permeability (ASTM C-1202), freeze/thaw durability (ASTM C-666), shrinkage (ASTM C-157), scaling (ASTM C-672), and hardened air properties (ASTM C-457) as performed by the Virginia DOT and Maryland State Highway Administration.

SET TIMES VARY

Although other testing has not shown the anti-microbial agent affects the set time of concrete, the testing at Oldcastle found the agent slightly retards the set of each of the designs used. Set-times (ASTM C-403) of concrete mixes vary greatly with material blends and batch procedures. Laboratory testing should be conducted before a design goes into production to conclude if this will be an issue.

This testing also included 12 test panels cast with and without the anti-microbial agent. These tests showed the anti-microbial concrete is effective in preventing the colonization and growth of not only *Thiobacillus,* but also a multitude of other nasty microbes.

This technology is not so new that it hasn't seen the outside of a laboratory. It's already under foot in many places across the country. The city of Atlanta began using anti-microbial concrete in its sewers in 1997. It's being used in six cities and counties in Virginia and four cities in Florida. It has been used from the Carolinas to Hilo, Hawaii, and from Allegheny County, Pa., to Fresno, Calif. To date, anti-microbial concrete has been preventing sewer corrosion in 14 states and the U.S. National Park Service. **PW**

— Ramsburg is the concrete technologist for High Concrete Structures Inc., Denver, Pa., and is a regular contributor to Hanley Wood's The Concrete Producer.