TECH NOTE

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Microbial Induced Corrosion (MIC) Attack of Concrete in Sewage Applications

It is well known that concrete often ages more quickly in sewerage applications. Why does this occur and what can be done to minimize such deterioration?

Both physical and chemical attack of concrete in sewage systems are possible. However the more prevalent of the two, by far, is chemical attack and the two most common chemical attack processes are sulfate attack and sulfuric acid attack. In the wastewater industry, the acid attack mechanism or cycle is normally referred to as Microbial Induced Corrosion of Concrete or MICC (sometimes shortened to MIC), and this TechNote focuses on this particular process. The photograph (below) of a wastewater treatment plant intake structure illustrates the significant impact MICC can have on concrete structures. The reinforcing steel (not clearly evident in the photo) was exposed in many wall locations indicating a loss of approximately 2” of concrete caused by MICC attack.

Household as well as certain industrial wastes contain organic matter that will start to breakdown or biodegrade within a short period of time. This is a process by which bacteria eat and digest the organic matter and, as with all living things, produce waste. The bacteria in sewage typically produce two kinds of waste depending on the oxygen level of the water. The dominant bacteria produce sulfur-oxygen compounds called “sulfates”. However, if the water flow is such that there is not enough turbulence to get sufficient air into the water, all of the oxygen will be quickly depleted and a secondary bacteria will take over. These secondary bacteria (sulfate reducing bacteria) will consume the sulfates in the sewage flow and form Hydrogen Sulfide as their waste product.

Hydrogen sulfide, in a natural room temperature state, is a gas and, while some will bubble out of the water, some, like carbon dioxide gas in soda, will stay in solution in the water. If the water is shaken or disturbed much of the dissolved gas, again like soda, will be emitted as bubbles. Hence, in sewage systems that have areas of slow or stagnant flow there will be a significant formation of hydrogen sulfide gas that will come out of solution and accumulate in sewerage elements where there is more turbulence. This is the process often seen in manholes, lift stations and the sewage entrance structures of wastewater treatment plants where stagnant or slow moving sewage undergoes sudden turbulence as pumps activate or flows fall into a receiving basin.

There is a misconception that hydrogen sulfide gas, in itself, is corrosive to concrete. It is not and, on its own, will not affect concrete to any significant extent. However, being heavier than air, hydrogen sulfide will settle on the surface of the sewage water but, as well, will also be circulated around a structure's air filled cavity through convective currents. The hydrogen sulfide gas will then re-dissolve in the water of the slime that adheres to the concrete walls. In solution in water the hydrogen sulfide forms a weak sulfuric acid. While this acid will slowly attack the concrete directly its more ruinous effect is in its lowering of the pH of the concrete surface from approximately pH 12.5 to pH 9. Carbonation is also a contributing factor in lowering of the surface pH of the concrete. At pH 9 and below other strains of bacteria can become established on the nearly pH neutral surface of the concrete.

The newly formed bacteria include Thiobacillus and it is this bacterium that is the primary cause of MICC in concrete sewage structures. Thiobacillus bacteria consume hydrogen sulfide gas and excrete sulfuric acid as waste. As the environment becomes more and more acidic, lesser strains of this bacterium die out to be replaced by more aggressive strains. The most aggressive strain of bacteria is called Acidiothiobacillus Thiooxadans (formerly Thiobacillus Thiooxadans). This strain can create an environment where the pH is as low as 0.5 which is equivalent to a 7% solution of sulfuric acid. This most aggressive strain of Thiobacillus bacteria is commonly found in the upper areas of a structure but research shows that the highest levels of bacteria and the ensuing degradation can also be found at any elevation of a sewerage structure. The diagram illustrates the effect of the process on a concrete pipe. Sulfuric acid will rapidly degrade the concrete and, through the chemical attack process, create sulfates. These sulfates further attack the concrete creating expansive degradation that causes the surface layer to fall away.

A standard Xypex treatment is an inexpensive and permanent way to improve concrete's resistance to acid and sulfate attack and to protect concrete in acidic environments as low as pH3 where low levels, or only occasional H_2S buildup is expected. The American EPA estimates that 95% of manholes have a pH environment of 3 or above and are therefore receptive to Xypex (either as an admix in the concrete or as a coating on an existing element) treatment for both waterproofing and chemical protection. The remaining 5% of manholes as well as many lift stations and headworks areas will be subject to higher levels of H_2S build-up leading to the development of MICC.

In these aggressive environments, Xypex Crystalline Technology along with another level of protection is warranted to prevent the development of, or provide protection against, acid and sulfate attack. Cast in membranes or post applied coatings can be used as a barrier between the acids and the concrete. The use of Xypex Admix in the concrete along with these treatments can help to protect them from being pushed off by negative side pressure created by normal ground water. This traditional approach to sewerage concrete protection is effective although it does introduce a long term maintenance requirement as the barrier coatings wear and need to be replaced.

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Responding to the need for effective protection of sewerage concrete Xypex recently introduced a stand-alone protective strategy that is effective in the higher H_2S environments (previously only protected by membranes.)

Xypex Bio-San C500 is an admixture for concrete that combines an integral anti-microbial technology with Xypex's long established crystalline chemistry. Bio-San contains bio-active mineral solids that become permanently fixed within the cement matrix impairing bio-film formation thus inhibiting the growth of acid causing sewer bacteria such as Thiobacillus. The antimicrobial initiates a two stage kill mechanism that stops the Thiobacillus bacteria from developing thereby preventing the formation of sulfuric acid. Doing so, the attack on concrete is reduced to the point that sewerage infrastructure can achieve 100-year life expectancies.

The production of hydrogen sulfide gas and the resulting MICC lowers the pH environment of many sewage structures leading to rapid deterioration and high maintenance costs. The Xypex treatment of concrete – with either Xypex coatings, standard Xypex Admix or Xypex Bio-San C500 admix in precast and poured-in-place concrete – is an excellent way to waterproof these structures as well as provide a strong level of chemical protection against the attack mechanisms inherent to sewerage concrete.

Contact your local Xypex Technical Services Representative for further information.