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Concrete Plant International
North America Edition

April 2016 2

BAUMA 2016 News **NEWS** Future of precast concrete elements **CONCRETE PRODUCTS** Röckelein focuses firmly on growth – their recent floor element manufacturing system is followed by a brand-new concrete block production line **CONCRETE PIPES AND MANHOLES** Unity of concrete pipe associations mirroring the industry's globalization **PRECAST CONCRETE ELEMENTS** New high-performance plant with machinery capacity of 12 pallets per hour opened in Thailand **READYMIX CONCRETE** Substantial upgrade to a ready-to-use mortar plant has challenged convention by adopting a new mixing technique

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ABTC
aci American Concrete Institute
American Concrete Pipe Association
bibm
mpa British Precast
icpi
IPHA
NATIONAL PRECAST
NPCA
NZCS
PCI

Xypex Chemical Corporation, Richmond BC, Canada

Protecting Precast Sewage Structures with Crystalline Technology

Premature deterioration of reinforced concrete structures has become a worldwide problem due to its excessive cost effect, environmental impact, and safety issues. Over the last number of years different countries and authorities have tried to quantify the impact in financial terms and the numbers can be staggering.

Several studies done in 1998 – 2002 showed that even then that in the USA alone, corrosion was causing sewer asset losses estimated at around $14 billion per year [1]. In Belgium the figure was estimated to be £4 million per year [2] (5.7 million USD at current rates), the cost of sewer rehabilitation due to corrosion damage in Germany was €100 million [3] (109 million USD) and in Sydney, Australia, sewer pipe rehabilitation was estimated at AUS$40 million [4] (28 million USD) with much of the cost due to pipe corrosion.

Both physical damage and chemical attack of concrete in sewage and septic systems is possible, but the more prevalent of these by far is chemical attack. The two most common forms of attack in this environment are acid attack and sulfate attack. In the wastewater industry, the acid attack mechanism is normally referred to as Microbial Induced Corrosion or MIC. This is a process whereby sulfides in the waste water stream are transformed by biological reactions into sulfuric acid and the sulfur compounds produced by this reaction will enter the concrete substrate and help to initiate sulfate attack.

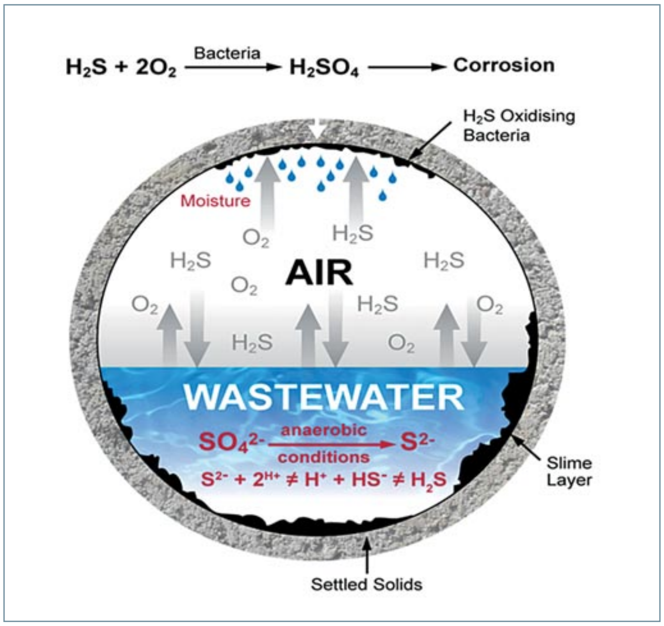
Household sewage and some industrial wastes contain organic matter which will break down and biodegrade in a relatively short period of time. This biodegradation is the chemical dissolution of sewage materials by bacteria, fungi, or other biological means. In a sewer or septic environment the bacteria most responsible for this are sulfate-reducing bacteria or SRB which reside in a slime layer below the water level.

SRBs, one of the oldest forms of microorganism with a history that extends back some 3.5 billion years, can reduce sulfate in large amounts to obtain energy and in turn produce sulfur compounds as a waste product. These sulfur compounds remain in the water and, where there is not enough turbulence to incorporate sufficient air into the water, the oxygen will be quickly depleted. In the resulting anaerobic (oxygen depleted) condition the bacteria will form hydrogen sulfide (H2S) as a waste product.

While some of the hydrogen sulfide gas will diffuse out of the water, a certain percentage will also stay in solution. If the flow of the sewer water is disturbed, a further significant amount of hydrogen sulfide gas will readily come out of solution and accumulate in areas of greater water turbulence such as manholes, lift stations and head work structures of wastewater treatment plants.

While hydrogen sulfide gas is not by itself damaging to concrete it will settle on the surface of the sewage water because it is heavier than air and get circulated around a sewer structure's air filled cavity through

MIC deterioration at a wastewater treatment plant intake structure with a loss of approximately 2" of concrete.



MIC corrosion process

The World Standard in Concrete Waterproofing by Crystallization

Enhanced Durability for Precast Concrete Structures

NO EQUAL

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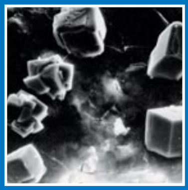
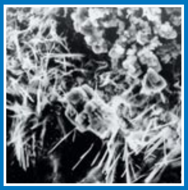


Concrete
(Untreated)



Xypex Crystallization
(Initiated)

Xypex Crystallization
(Mature)

Buried precast concrete products are susceptible to water infiltration and concrete deterioration. Manholes and septic tanks are especially vulnerable to sulfate and acid attack caused by microbial induced corrosion. Xypex Admix provides a unique solution to these problems. When added to the concrete mix, it provides integral waterproofing as well as increased acid resistance and sulfate protection. When you select Xypex you've chosen the best – more than 40 years of independent testing and still *No Equal*.

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convective currents. This, along with carbon dioxide gas that is normally found in sewer structures will dissolve in the moisture that adheres to the concrete walls above the flow line and creates both a weak sulfuric acid and carbonic acid on the interior surface of the sewer structure. This results in a lowering of the pH level at the surface of the concrete from 12.5 down to a pH of 9. At higher pH levels the alkaline surface of concrete is not conducive to colonization by bacteria but over time, the pH of the concrete surface is slowly reduced by both carbonation and the neutralizing effect of hydrogen sulphide in the form of dilute sulfuric acid. Once the pH of the concrete surface drops below 9 and there are sufficient nutrients as well as the presence of moisture and oxygen, the colonization by sulfur bacteria will begin thus initiating the process known as microbial induced corrosion (MIC).

Acidithiobacillus Bacteria

Typically this starts with T. Thioparus which is the first strain of bacteria to colonize the surface of sanitary and septic sewer structures. As this strain of bacteria continues to consume sulfur compounds it produces waste products with a more concentrated acid further reducing the pH level at the surface of the concrete. As this level drops it is colonized by another species of bacteria which is able to exist at the lowered pH level while the original bacteria die off due to the reduced pH at the surface of the concrete.

This colonization and die-off of different bacteria continues until the ultimate colonization of T. Thiooxidans which is able to live in an environment where the pH level is as low as 0.5 which is roughly equivalent to a 5% solution of sulfuric acid. Once this point is reached it will cause severe acid attack and as sulfate ions penetrate into the concrete substrate it will also cause an expansive sulfate attack further opening up the concrete to even more destruction. MIC is site specific and time specific in terms of corrosion and not all of the concrete structures in a sewer collection system are subject to this type of attack. As long as the flow rate in the sewer is either 2 f/s (feet per second) or greater then there is generally not a problem. At a rough estimate, approximately 5% of a sewer system will be susceptible to corrosion and most municipal authorities are aware of where the problem areas will be, either based on local and historic knowledge or hydrogen sulfide modeling software.

Not all concrete in a sewer environment will be affected to the ultimate degree but once the surface of the concrete has been reduced to a pH 4.5 – 5 range you can begin to get some initial deterioration in Portland cement structures. Depending on the volume of hydrogen sulfide gas the rate of deterioration may be anywhere from 1mm – 20mm per year.

There are various ways to increase concrete's resistance to acids. These include proper mix design to reduce the permeability of the concrete, enhanced mix design to withstand mild acid attack and finally, in extreme cases, the use of a suitable coating to protect it from acid and sulfate attack.

Diffusion or penetration of aggressive substances into concrete through the interconnected pores (e.g. capillary pores) and cracks causes material degradation and deterioration of the structure. Depending on the nature of the diffusive substances, they can attack concrete or the steel reinforcement. By blocking the pores and healing cracks, the mass transfer rate into the concrete will be decreased resulting in the enhancement of concrete's durability and extension of the structure's service life.

Traditional means for improving the durability of the concrete are through reduction of the water/cement ratio (W/C) and increasing of moist curing time. More recently, partial replacement of the Portland cement with supplementary cementitious materials (SCMs) such as fly ash and ground granulated blast furnace slag (GGBFS) has become more popular for increasing the durability of concrete exposed to aggressive environments but it has been observed that these criteria are often not enough by themselves to produce a durable or high performance concrete.

Despite all efforts and attempts to increase the durability of concrete exposed to severe sewer environments, the problem still exists. This has been the motivation to produce permeability-reducing admixtures that can considerably reduce moisture and chemical transfer into the concrete. However, these admixtures should not only reduce the permeability of the concrete but also enhance resistance to chemical attack of the concrete.

Crystalline Technology

Xypex crystalline technology is one solution to reduce the permeability of the concrete which has shown a significant improvement in enhancing the performance of concrete durability. This material is designed to react with the by-products of cement hydration in the capillary tracts and voids of concrete to produce a crystalline structure which blocks up the natural porosity found in concrete.

All forms of deterioration need these paths and passages in order to diffuse into the concrete. If we block the pores, capillary tracts and micro-cracks we will significantly reduce the rate of diffusion of these liquids and gases thus protecting concrete structures against and the effects of acids and sulfate attack.

In addition to visual evidence of the crystalline formation in the voids of concrete through electron microscope images, independent tests confirm the ability of crystalline technology to significantly extend the service life of concrete structures. The result of this increased durability and longevity is less maintenance and repair work, and dramatically improved sustainability.

Crystalline materials are available in powder form that can be incorporated as an admixture into a concrete mix design for new structures or mixed with water into a slurry for brush or spray application on the surface of existing concrete structures.

Xypex crystalline technology is an effective and inexpensive way to help protect concrete in acidic environments as low as pH 3 while also performing as a 'belt-and-sus-

Table 1: overview

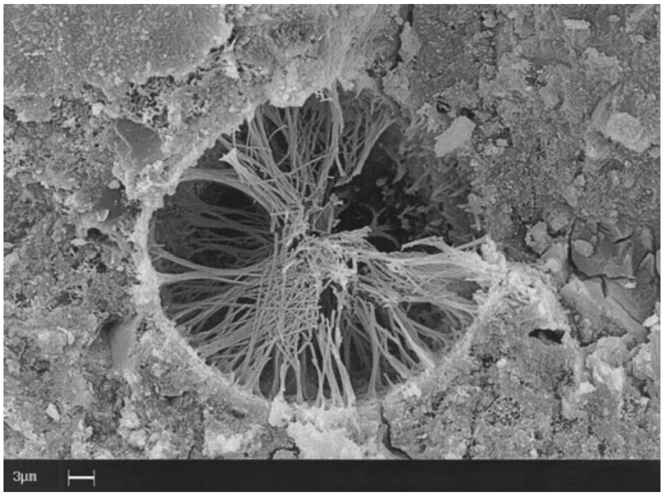
Species	Preferred Substrate	Preferred pH growth range
T. Thioparus	H_2S, S^0, $S_2CO_3^{2-}$	5-9
T. Novellus	$S_2CO_3^{2-}$	2.5-8
T. Intermedium	$S_2CO_3^{2-}$	2.5-8
T. Neapolitanus	S^0, $S_2CO_3^{2-}$	3-7
T. Thiooxidans	H_2S, S^0	0.5-3

Precast concrete manholes manufactured with crystalline technology incorporating red pigment for easier identification.

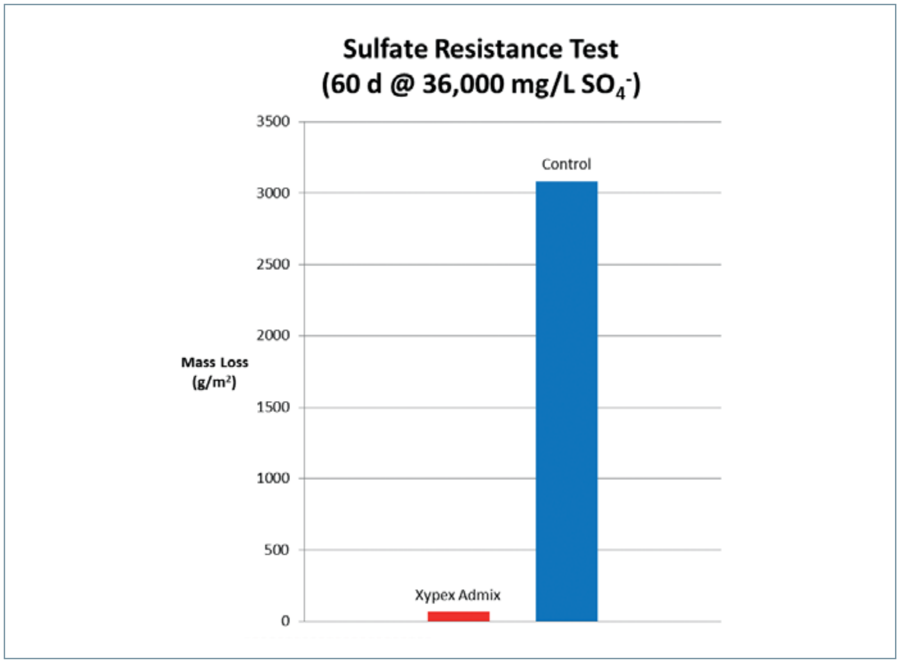
penders' secondary line of defense in highly acidic environments. The U.S. Environmental Protection Agency estimates that 95% of manholes have an environment with a pH of 3 or above, making them suitable for a Xypex stand-alone treatment for waterproofing and chemical protection. The remaining 5% of manholes, having an even more aggressive environment would benefit from treatment with Xypex Crystalline Technology and some other level of protection against such highly aggressive MIC attack.

In accelerated sulfate corrosion testing, 150mm square cubes cast utilizing C30/37 classified concrete and exposed to a highly concentrated sulfate solution (36,000 mg/l) for 60 days. Following exposure, all samples were weighed and examined for surface deterioration. The samples formulated with Xypex Admix C-1000 NF had a weight loss of between 38.6 and 90.5 g/m^2, and visual examination showed only minor deterioration at the edges while the control samples had a mass loss between 2,473.0 and 3,693 g/m^2 and visual examination showed significant surface deterioration over the entire surface of the cubes.

Based on this testing, there is clear evidence of Xypex's crystalline chemistry's effectiveness in providing significant increased resist-



Scanning Electron Microscope image of crystalline formation in a concrete pore.



Accelerated sulfate corrosion test results.

Terrebonne Parish manoles with crystalline admix show little deterioration after 10 years of service.

ance when exposed to difficult sulfate conditions.

Case Study

Xypex Admix C-1000 Red was utilized in the manufacture of approximately 30 precast manholes in 1999 for the Clinton St. Sewer Collection Project in Terrebonne Parish, LA. Xypex Admix was specified for waterproofing and provide chemical protection against degradation of concrete surfaces exposed to acid and sulfate attack. Xypex Admix with a red pigment was used for easy identification and verification of manholes treated with Xypex Admix.
The manholes for the Clinton St. Sewer Collection project were inspected in August 2010 and found to be in excellent condition showing no signs of deterioration whatsoever after over 10 years of exposure.

Conclusion

Durability of the concrete depends on various parameters. In a sewer environment the permeability and chemical resistance of the concrete are especially important. The diffusion rate of aggressive substances is controlled by permeability of the concrete. Lower permeability means that it is more difficult for water and corrosive agents to penetrate the concrete. To produce a watertight concrete, the influencing factors on concrete permeability such as water to cement ratio, cement content, coarse aggregate proportions, aggregate grading along with good quality of concrete practices such as proper vibrating and suitable curing method and duration must be considered. The effect of Xypex Admix on concrete permeability and chemical resistance is well documented. All test results confirmed that Xypex Admix significantly enhances the quality and watertightness of precast concrete products.

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FURTHER INFORMATION

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