TechNote

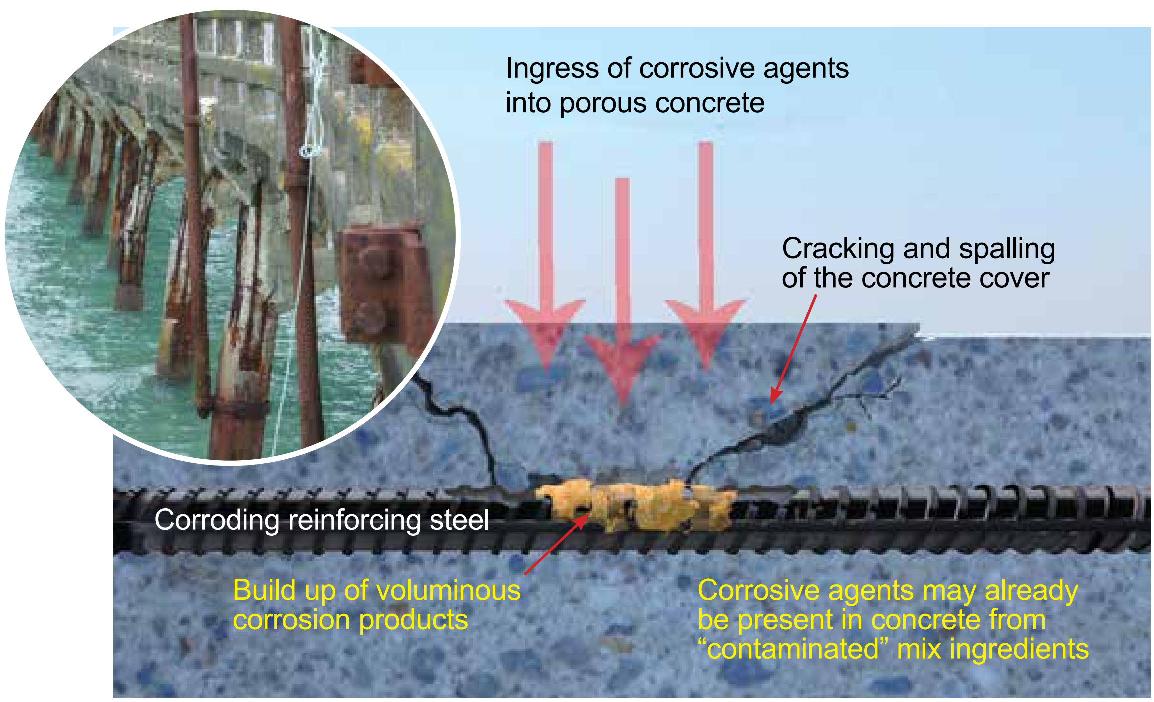
Jim Caruth
P.Eng.
Technical Services
Manager

Corrosion Resistance of Xypex-Treated Concrete

While Xypex Admixtures and Coatings are recognized throughout the world as reliable treatments for the waterproofing and protection of both new and existing concrete structures, the ability of Xypex Crystalline Technology to improve reinforced concrete's resistance to the damaging and very costly effects of various chemicals (specifically, chloride salts) is not as well known. Chlorides are arguably the largest contributor to concrete deterioration and the degradation of infrastructures. The associated costs are likely measured in trillions of dollars worldwide and are increasing. Concrete structures susceptible to chloride attack include those in salt water marine environments (piers, seawalls), surface transport (bridges, parking garages), and foundations in brackish soils.

Concrete Corrosion

Chlorides that are dissolved in water, penetrate slowly through sound concrete but very rapidly through its cracks. These chlorides can quickly degrade reinforced concrete by accelerating the corrosion of the steel embedded in it. Iron oxide (rust) occupies a volume several times larger than the original steel and, as there is no room for volume change within the concrete substrate, the resulting stress will eventually create cracking. These cracks allow the chloride-laden-water to reach the steel even faster, accelerating the corrosion cycle and ultimately resulting in the need for costly repairs.



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Corrosion Resistance of Xypex-Treated Concrete (cont'd)

Xypex Crystalline Technology

Xypex Crystalline Technology prevents the ingress of water by, in effect, shutting down the pores and micro-cracks in the cement matrix and by bridging small cracks within the concrete mass. Since testing has shown that Xypex-treated-concrete will prevent water from reaching reinforced steel even under extreme hydrostatic pressure, it follows that the chlorides dissolved in this water will also not reach the steel, thereby slowing or stopping the corrosion cycle. While other strategies are available for densifying concrete and for reducing the diffusion rate of chlorides, most are ineffective in dealing with cracks.

Xypex, in contrast, is one of the only strategies that will prevent the diffusion of chlorides in the sound concrete while also closing the leak paths caused by the micro and macro cracks that inevitably occur.

Significant independent research has been conducted to determine Xypex's effectiveness in reducing chloride-based concrete degradation. The following table briefly summarizes the results from some of the research conducted on Xypex's ability to prolong the service life of concrete in a chloride environment.

LABORATORY TESTING RESULTS			
Date	**Material**	**Testing Agency**	**Results**
Aug. 1, 1979	Coating	Twin City Testing and Engineering Laboratory, Inc, Minnesota, USA	ASTM C672 testing was used to evaluate the ability of Xypex Coatings to reduce the ingress of chlorides into concrete. The Xypex coated samples had up to 50% lower chloride concentration at depths of 1" (25 mm) to 5" (125 mm).
Mar. 1, 1996	Admixture	Mahaffey Associates, New South Wales, Australia	0.40 W/cm ratio concretes incorporating Xypex and a commercially available pore blocker were tested. The Xypex treated samples showed a 50% - 60% improvement in chloride diffusion coefficients as compared to both control mixes and the pore blocker treated mixes.
Nov. 1, 1998	Coating	Building Materials Testing Center, Tokyo, Japan	Over a 270 day period, concrete samples were subjected to 12 hours of salt spray followed by 12 hours drying. At $\frac{5}{8}$" (15 mm) depth the Xypex treated samples had $\frac{1}{3}$ lower chloride content than the control samples.
Dec. 1, 2002	Admixture	Department of Transportation, New Jersey, USA	The performance of Xypex C-1000 against 3 commercially available corrosion inhibitors was evaluated. Based on the results, the researchers recommended the use of Xypex Admixture to reduce the ingress of chemicals into concrete.
Mar. 1, 2003	Admixture	University of New South Wales, Australia	Modified ASTM C1202 testing, NT Build 443 - 35 day sodium chloride ponding testing, and ACCI Chloride Diffusion Testing were completed on 0.55 w/cm ratio (32 MPa, 4500 psi commercial grade) 20% FA and 38% slag concretes. Lifecycle modeling showed a 5 time increase in the expected time to corrosion for the Xypex / slag mix and a 2 time increase for the Xypex / FA mix.

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Date	Material	Testing Agency	Results
May 1, 2004	Admixture	University of New South Wales, Australia	Modified ASTM C1202 testing, NT Build 443 - 35 day sodium chloride ponding testing and ACCI Chloride Diffusion Testing was done on 0.40 w/cm ratio (40 MPa, 6000 psi commercial grade) 20% FA, 38% slag and 60% slag concretes. The lifecycle modeling showed increased times to corrosion for all Xypex modified mixes of between 1.5 times to 4.25 times.
Nov. 1, 2005	Coating	Honnun Ltd, Reykjavik, Iceland	A bridge constructed in 1972 and subject to chloride de-icing chemicals was coated with Xypex Concentrate in 1993. In 2005, cores from the bridge abutment were extracted and examined. Testing showed that Xypex coatings reduced chloride diffusion coefficients by 15%.
Oct. 1, 2011	Admixture & Coating	Sirindhorn International Institute of Technology, Thammasat University, Bangkok, Thailand	0.4 and 0.5 w/cm ratio concrete samples were immersed in a chloride solution for 9 months. The study concluded that for both cement and cement/fly ash mixes Xypex reduced chloride ingress into the concrete in both coating and admixture treated samples.

Field Testing Results

In addition to the above laboratory testing, several field investigations also show Xypex's effectiveness at reducing chloride attack:

Bridge Test (Wisconsin)

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The University of Wisconsin-Milwaukee did field testing on nine bridges that had been treated with various corrosion mitigation strategies including surface sealers and three different admixtures. The Xypex-treated bridge was constructed in 1995 in a manner that left areas of the bridge decks as control sections. The bridge was cored in 2000 and chloride concentrations taken at several depths including that of the reinforcing steel. The study found Xypex to be the only admixture to significantly reduce chloride ingress into the concrete. At a 2" (50 mm) depth, the Xypex treated bridge section showed an average 55% reduction in chloride content as compared with the control section.

Recently, field reviews were completed for two Xypex-Admix-treated concrete structures that had been in service for 19 years:

Cronulla Marina (Australia)

In 1994, a concrete float at the Cronulla Marina near Sydney Australia was cast with Xypex Admix. The deck slab is 4" (100 mm) thick with the top reinforcing at 1.5" (40 mm) from the top surface. In 2013 the float was surveyed by the engineering firm of BCRC, New South Wales, Australia. The investigation included visual inspection, half cell testing and concrete sampling at various depths to determine chloride contents and to develop a chloride diffusion coefficient for the concrete. Test results allowed life cycle modeling that resulted in a projected time to corrosion of 129 years from the time of the test.

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Lascelles Wharf (Australia)

In 1995, the Lascelles Wharf at Geelong Ports near Melbourne, Australia, a large bulk materials wharf, was built with Xypex-Admix-treated concrete. In January 2014 a survey including visual condition assessment, depth of concrete cover and chloride content assessment was completed. The concrete cover was found to be 51 mm - 76 mm (2" - 3") and life cycle modeling based on the concrete covers and the chloride diffusion coefficients from the samples taken predicted time to corrosion results of 156 - 175 years from the time of the test depending on the depth of cover.

The above field reviews indicate that, from the date of commissioning, the time to corrosion for these Xypex Admixture modified structures is estimated at between 150 and 200 years. While this level of projected service life is excellent, the results are considered even more remarkable given both the low to moderate depth of concrete cover, and the extremely harsh South Pacific marine environment in which these structures are located.

Summary

Both laboratory testing and long term field experience show that Xypex Crystalline Technology is a proven strategy for extending the service life of new concrete structures subjected to harsh chloride environments. In the case of existing concrete structures, testing also confirms that Xypex Coatings will provide excellent chloride protection and help extend the service life of the concrete.

Contact your local Xypex representative or Xypex Technical Services for more information.