Migrating Corrosion Inhibitors: A Positive Invasion Against Corrosion

by Julie Holmquist, Cortec Corporation

Corrosion is a serious enemy of reinforced concrete bridges, especially those exposed to deicing salts or salt-water spray. As bridges age, the high pH environment of new concrete—which initially protects steel reinforcement from corrosion—declines through carbonation. When moisture, oxygen, and chlorides seep into the concrete pores, they foster an environment for the reinforcement to rust. The pressure of the rusting reinforcement causes the concrete to crack and spall. The damaged concrete allows corrosive elements greater access to the reinforcement, accelerating the corrosion cycle and damaging the bridge. Accelerated corrosion and damage are a serious concern because bridges are complex and expensive structures to design, build, and replace.

Migrating Corrosion Inhibitor Technology

While it is not possible to fully stop corrosion, there are many strategies to slow corrosion and extend service life. Among these are migrating corrosion inhibitors, which have been in use for more than 30 years. These products, including some that are patented, come in a variety of delivery methods, giving flexibility for use in the construction, repair, or maintenance of new or existing bridge structures.

Migrating corrosion inhibitors are based on salts of amine alcohols or amine carboxylates. They have the ability to work their way through concrete pores to reach the surface of the

Migrating corrosion inhibitor powders were used to protect post-tensioning strands on the St. Croix Crossing Bridge between Minnesota and Wisconsin. During this multi-year project, tendon grouting was sometimes delayed by cold weather. Photo: Minnesota Department of Transportation.

A 100% silane sealer containing migrating corrosion inhibitors was applied to the deck of the Francis Scott Key Bridge in Baltimore, Md., as part of routine maintenance in 2008. The manufacturer recommends another application this year. Photo: Cortec Corporation.

Table 1. *ASTM C1582 Physical Property Results for Migrating Corrosion Inhibiting Admixture A*[2]

	Control	Migrating Inhibitor A	Relative to Control	ASTM C1582 Requirement	Result
Setting time, minutes					
Initial set	312	431	+119	≤ ±210	OK
Final set	404	524	+120	≤ ±210	OK
Compressive strength, psi					
3-day	3290	3647	111%	≥ 80%	OK
7-day	4070	4377	108%	≥ 80%	OK
28-day	5143	5330	104%	≥ 80%	OK
6-month	6077	6650	109%	≥ 80%	OK
1-year	6463	6877	106%	≥ 80%	OK
Flexural strength, psi					
3-day	585	591	101%	≥ 80%	OK
7-day	661	691	105%	≥ 80%	OK
28-day	757	797	105%	≥ 80%	OK
Shrinkage, %					
Length change	–0.025	–0.021	+0.004 84%	≤ 0.010 ≤ 135%	OK
Durability, RDF					
Freeze/thaw durability	99.1	98.8	99.7%	RDF ≥ 80%	OK

Table 2. *ASTM C1582 Corrosion Results for Migrating Corrosion Inhibiting Admixture B*[3]

	Control	Migrating Inhibitor B	Relative to Control	ASTM C1582 Requirement	Result
Mean integrated current, C	155	29	n/a	≤ 50 C when control is 150 C	OK
Mean area corroded, in.^{2}	8.93	2.36	0.26	≤ ⅓ of control	OK
Mean chloride content, ppm*	2861†	2898	101%	≥ Critical chloride content	OK

*Based on control average at 50 coulombs plus 1 standard deviation.

†Critical chloride content

reinforcement and form a protective molecular layer on it. This layer interferes with the natural corrosion reaction that takes place when oxygen, moisture, and chlorides are in contact with steel. As a result, corrosion is delayed or reduced once started.

Uses in New Construction

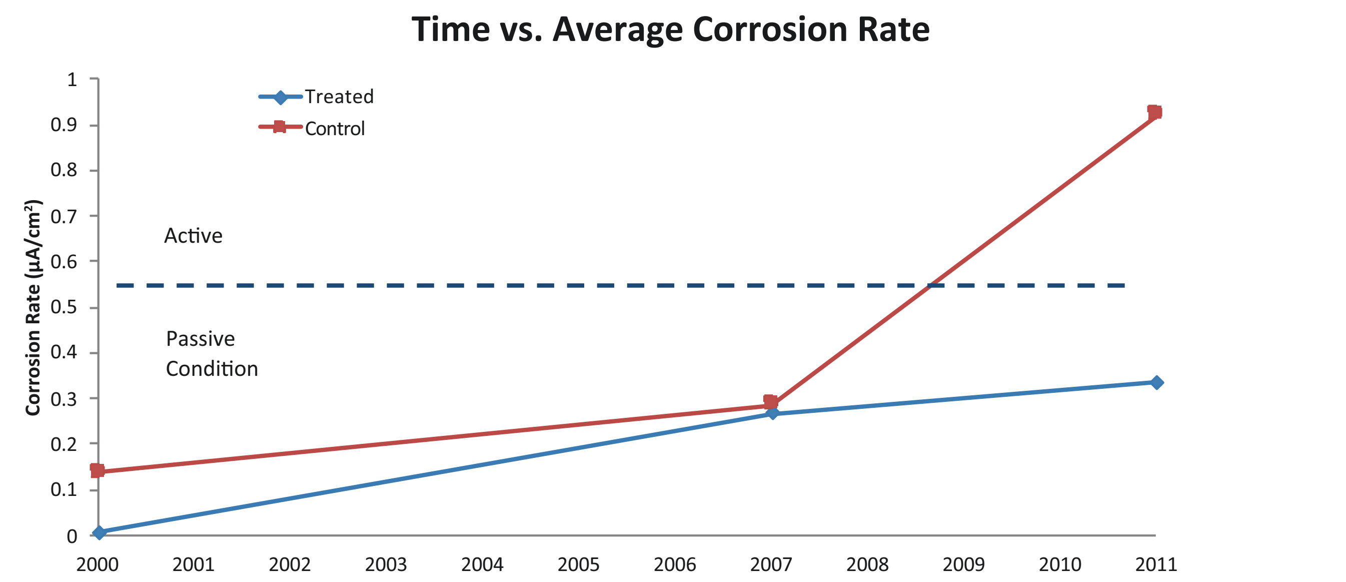
Migrating corrosion inhibitor admixtures can be mixed directly into the concrete mixture. Some meet ASTM C1582[1] physical property standards for set time, compressive strength, flexural strength, shrinkage, and freeze/thaw durability (see **Tables 1** and **2**).[2,3] They may also meet ASTM C1582 requirements for corrosion reduction in a chloride environment.

Unlike calcium nitrite, which has a high tendency to leach into water, several migrating corrosion inhibitor admixtures have been UL certified to meet NSF/ANSI Standard 61[4] for use in potable-water structures. In some cases, migrating corrosion inhibitors can be added to shotcrete and repair mortars.

For post-tensioned bridges, a low-pressure air hose can be used to blow migrating corrosion inhibitor powder through post-tensioning ducts to protect post-tensioning cables before grouting, as was done on the St. Croix Crossing Bridge over the Mississipi River between Wisconsin and Minnesota when cold weather delayed tendon grouting (see the Fall 2018 issue of *ASPIRE* for an article on the project). With this method, the ducts are capped, and the low-toxicity corrosion inhibitor vaporizes and disperses throughout the void space, forming a protective molecular layer on the post-tensioning strands. Little or no surface preparation is required before the powder is applied, and the powder does not need to be flushed out before grouting.

Uses for Repair and Maintenance

Migrating corrosion inhibiting admixtures can also be used in repair applications to discourage further corrosion where corrosion damage has already occurred, as was done on the Randolph Avenue Bridge in St. Paul, Minn., where winters are harsh and deicing salts are regularly used. By 1986, the bridge, which was built in 1963, was in need of an overlay repair. The westbound lanes had more damage than the eastbound lanes and were overlaid slightly thicker (0.31 in. deeper on average), using a concrete mixture with a migrating corrosion inhibitor admixture. To serve as a control, the eastbound lanes were overlaid with the same concrete mixture but no inhibitor. Corrosion rates in the treated side remained lower, while corrosion rates in the eastbound control lanes spiked into the active range between the 2007 and 2011 readings.[5]



Randolph Avenue Bridge corrosion rates. Figure: Cortec Corporation.

Surface-applied migrating corrosion inhibitors can be applied to existing structures during repair or maintenance. These inhibitors enter concrete pores first as a liquid by capillary action and then by vapor diffusion, with the advantage of protecting reinforcement that has already been embedded under the surface. In "pure" inhibitor form (no water repellant), the inhibitor can migrate up to 3 in. deep to slow deterioration of reinforcement that may have started to rust beneath the concrete surface. It can also be combined with 40% or 100% silane sealers to discourage water and contaminant intrusion at the surface and provide inhibitor protection beneath.

Conclusion

Migrating corrosion inhibitors offer several innovative and easy-to-apply strategies for fighting corrosion on bridges. They have the advantages of being useful on new and existing structures and being highly compatible with concrete mixtures. Additionally, they are good candidates for use near waterways due to their low toxicity and NSF/ ANSI 61 Standard certifications for use in potable-water structures.

Migrating corrosion inhibitors were tested in an overlay repair on the Randolph Avenue Bridge in St. Paul, Minn. Photo: Cortec Corporation.

While migrating corrosion inhibitors are minimally invasive to the concrete structure as a whole, they are a positive force to "invade" concrete for the purpose of reducing corrosion on new and existing bridges.

References

1. ASTM International. 2017. *Standard Specification for Admixtures to Inhibit Chloride-Induced Corrosion of Reinforcing Steel in Concrete*. ASTM C1582/ C1582M-11(2017)e1. West Conshohocken, PA: ASTM International.

2. Ade, K., et al. 2016. "Admixture to Inhibit Chloride-Induced Corrosion of Reinforcing Steel in Concrete (ASTM C1582)." Prepared for Cortec Corporation by Tourney Consulting Group, Kalamazoo, MI, April 14, 2016.

3. Ade, K., et al. 2016. "2005 NS Admixture to Inhibit Chloride-Induced Corrosion of Reinforcing Steel in Concrete (ASTM C1582)." Prepared for Cortec Corporation by Tourney Consulting Group, Kalamazoo, MI, May 27, 2016.

4. NSF International. 2016. *Drinking Water System Components–Health Effects*. NSF/ANSI 61. Ann Arbor, MI: NSF International.

5. Meyer, J. 2017. "Organic Corrosion Inhibitors—New Build and Existing Structures Performance." Paper presented at the Brian Cherry International Concrete Symposium, Australian Corrosion Association, Melbourne, Australia.

Julie Holmquist is content writer at Cortec Corporation in St. Paul, Minn.