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Corrosion Inhibiting Admixtures for Reinforced Concrete—A State of the Art Report

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NACE International
15835 Park Ten Place
Houston, Texas 77084-5145
+1 281-228-6200

Foreword

NACE technical committee reports are intended to convey technical information or state-of-the-art knowledge regarding corrosion. In many cases, they discuss specific applications of corrosion mitigation technology, whether considered successful or not. Statements used to convey this information are factual and are provided to the reader as input and guidance for consideration when applying this technology in the future. However, these statements are not intended to be recommendations for general application of this technology, and must not be construed as such.

The purpose of this technical committee report is to present state of the art information on corrosion inhibiting admixtures. It is intended to provide specifiers, designers, and corrosion control personnel information to control the corrosion of conventional reinforcing steel in hydraulic cement concrete using corrosion inhibiting admixtures. For more information on design, evaluation, maintenance, and rehabilitation of reinforced concrete structures, refer to NACE SP0187,[1] SP0390,[2] and SP0308.[3] Further information on concrete technology can be found in the American Concrete Institute (ACI)[(1)] Collection of Concrete Codes, Specifications, and Practices.[4]

Corrosion inhibitors are defined in general in NACE/ASTM[(2)] G193.[5] Admixtures are defined in ACI Concrete Terminology.[6] Corrosion inhibiting admixtures are described in ACI 222R.[7] ASTM C1582/C1582M[8] further describes corrosion inhibitors. The section on Definitions explains the terminology in this document.

This report describes several types of materials used as corrosion inhibiting admixtures, their selection and evaluation, their proportioning into freshly mixed concrete, and their effects on fresh and hardening/hardened concrete. Corrosion inhibiting admixtures may help delay corrosion initiation and extend the interval of corrosion propagation. However, the corrosion of reinforcing steel in concrete depends on factors beyond the presence of corrosion inhibiting admixtures, including the service environment, the quality of the concrete, the environmental exposure of the structure, the formation and presence of cracks, the cover of the reinforcing steel, and other factors.

This report covers only admixed corrosion inhibitors used in reinforced concrete. Migrating corrosion inhibitors applied on hardened concrete and other corrosion inhibiting substances are beyond the scope of this document.

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Key Words

Reinforced concrete, reinforcing steel, corrosion inhibiting admixtures, ACI 212.3R, TG 050

* Chairman Fred Goodwin, EB Global Corrosion Competency Center, BASF Corporation.
(1) American Concrete Institute (ACI), 38800 Country Club Dr., Farmington Hills, MI 48331-3439.
(2) ASTM International (ASTM), 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

Introduction

Steel in concrete is normally protected from corrosion by the high pH of the concrete environment, which creates a stable passivation layer of iron oxides and hydroxides on the steel surface. Chlorides, however, can penetrate this layer and soluble iron chloride complexes form that weaken this layer because of the increased solubility of the iron. These iron chloride complexes allow iron to migrate from the bar surface outward in the cement paste, which leads to active ongoing corrosion of the steel.

Other causes of corrosion of steel in concrete are carbonation, galvanic attack between dissimilar metals, and stray current corrosion from external sources of direct current (see ACI 222R, ACI 201.2, and NACE Publication 01110).[7,10,11]

Corrosion inhibitors for steel in concrete are generally tested with chlorides, and some have been evaluated for carbonation-induced corrosion. Corrosion inhibitors for carbonation induced corrosion are discussed in Trabanelli (2005) and Söylev (2008).[12,13] There is currently no technical information on the effectiveness of corrosion inhibitors for stray current or galvanic corrosion.

Corrosion reduces the cross-sectional area of the reinforcing steel and often leads to spalling of the concrete over it because of the increased volume of the corrosion products. For these reasons, admixtures that mitigate the corrosion process are useful in extending the life of concrete structures, sometimes by themselves, sometimes in conjunction with other techniques to limit the intrusion of chlorides.

In evaluating corrosion inhibitors, it is worth noting that in some accelerated tests, the chloride intrusion rate can be so rapid that samples just going into corrosion are found to have higher chloride ion (Cl^-) concentrations because the concentration rises so quickly, the actual initiation concentration is exceeded. For this reason, highly accelerated testing is inappropriate for determining corrosion thresholds both with and without corrosion inhibitors. However, such tests may be utilized to demonstrate that a given material is an inhibitor.

Testing according to ASTM C1582/C1582M[8] describes a corrosion inhibitor as showing a reduction in corrosion rate and corroded area of bars in concrete containing chloride at a level above the level that induced corrosion in reference test specimens. As the methods are accelerated, they indicate only that the admixture is a corrosion inhibitor, and not the level of corrosion protection provided in service. Techniques or materials that reduce the actual intrusion of chloride, while being useful, are not corrosion inhibitors. Most corrosion protection systems employing corrosion inhibitors today also use various methods to reduce chloride intrusion to be efficient in the use of the corrosion inhibitor, and combine this with a conservative depth of concrete over the reinforcement.

These methods may include, but are not limited to, reducing the water-to-cementitious materials ratio (*w/cm*), inclusion of various supplementary cementitious materials that reduce permeability, and the use of a variety of organic materials that restrict wetting. An advantage of corrosion inhibitors lies in their ability to extend time to corrosion without requiring an extreme reduction in permeability, because systems that attempt to protect against corrosion entirely by restricting chloride ingress may have problems with placement because of rheological properties, early-age cracking (high-silica fume contents and very low *w/cm*), specification for extended curing (high pozzolan levels), or restricted strength development at early ages (high pozzolan and slag). Some of these effects may reduce the actual corrosion protection afforded, especially if cracking results. Therefore, the use of moderate levels of corrosion inhibitor with moderate levels of permeability reduction from supplementary cementitious materials may result in the needed protection while resulting in concrete that is easier to place.[14] Corrosion inhibitors that intrinsically reduce the permeability of the concrete also may provide this protection without the need for supplementary materials.

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