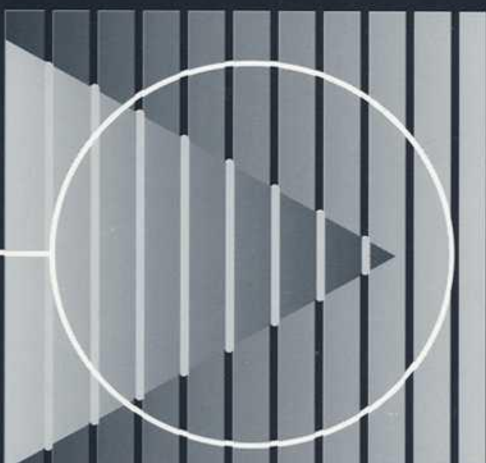
Techniques to Assess the Corrosion Activity of Steel Reinforced Concrete Structures



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Peer Review Policy

Each paper published in this volume was evaluated by three peer reviewers. The authors addressed all of the reviewers' comments to the satisfaction of both the technical editor(s) and the ASTM Committee on Publications.

To make technical information available as quickly as possible, the peer-reviewed papers in this publication were prepared "camera-ready" as submitted by the authors.

The quality of the papers in this publication reflects not only the obvious efforts of the authors and the technical editor(s), but also the work of these peer reviewers. The ASTM Committee on Publications acknowledges with appreciation their dedication and contribution to time and effort on behalf of ASTM.

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Foreword

This publication, *Techniques to Assess the Corrosion Activity of Steel Reinforced Concrete Structures,* contains papers presented at the symposium of the same name, held on 7 December 1994. The symposium was sponsored by ASTM Committees G-1 on Corrosion of Metals and C-9 on Concrete and Concrete Aggregates. Neal S. Berke of W. R. Grace and Company in Cambridge, MA; Edward Escalante of NIST in Gaithersburg, MD; Charles K. Nmai of Master Builders in Cleveland, OH; and David Whiting of Construction Technology Labs in Skokie, IL, presided as symposium chairmen and are editors of the resulting publication.

Contents

Overview

The deteriorating infrastructure is a topic of major importance throughout the world. Steel reinforced concrete is one of the most widely used construction materials, and as such, many of the deteriorating structures are of reinforced concrete. This has occurred even though steel-reinforced concrete is very durable, because this very durability has led to its use in aggressive environments.

The purpose of the symposium, in which the papers in this special technical publication (STP) were presented, is to explore techniques to determine the corrosion activity of steel in reinforced concrete field structures. This is not an easy task due to the fact that the steel is not visible, concrete has a high resistivity, and the structures are in use. Furthermore, the structures are orders of magnitude larger than typical laboratory specimens and traditional techniques, such as mass loss measurements and visual appearance of embedded steel are not practical.

ASTM Committees G-1 on Corrosion of Metals, in particular G01.14 on Rebar Corrosion, and C-9 on Concrete jointly sponsored the symposium. Both committees have active efforts in determining corrosion rates and other factors such as permeability to the ingress and chloride as well as other concrete properties that could affect performance. These committees have been involved in producing several STPs related to the performance of concrete and steel-reinforced concrete in the environment.

There are 13 papers in this STP that have been grouped into three major headings: Modeling, Corrosion Rate Measurements, and Case Studies. All of the papers address more than one of these topics and several others; however, the major emphasis is in the area of the major heading. Several of the papers address new methods of assessment or look at older methods with new approaches, that are in some cases, controversial. The editors encourage the readers to evaluate for themselves conclusions based upon the evidence given in the papers and the included references. As a whole, the papers presented give a broad overview that can be used in the assessment of steel-reinforced concrete in the field.

Modeling

The five papers in the Modeling section deal with using assessment information to predict remaining service life, service life of similar newer structures, or current condition. They combine the use of electrochemical measurements such as corrosion potential and corrosion rate measurements.

The papers by Newhouse and Weyers and Andrade and Alonso address using corrosion rate measurements to predict time to cracking. The first paper showed that chloride contents and changing environmental conditions played major roles and that corrosion rate measurements were far from accurate. They also showed that Bazant's model for time to cracking underestimated the times.

Andrade and Alonso looked at various approaches used to predict chloride ingress or carbonation front movement. These techniques were combined with corrosion rate measurements and predicted corrosion product build-up to develop models to predict remaining service life or service life of new structures.

Berke and Hicks determined chloride profiles for several field structures to calculate effective diffusion coefficients. These values were used to predict future chloride profiles from which time to corrosion initiation could be estimated. They showed that laboratory predictions of diffusion coefficients based upon Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration (ASTM C 1202) were in good agreement with field measurements on the same concrete. The potential benefits of using corrosion inhibitors to significantly increase the threshold value of chloride for corrosion initiation were shown.

Kranc and Sagüés, and Hall et al. discussed the use of models based on finite element analyses. Kranc and Sagüés show how finite difference computations can be used to correct underestimations of the corrosion rates in large marine structures. Hall et al. use finite element analysis of corrosion potential data on buried pipe to detect corroding areas and to identify the detection limits of potential surveys.

Corrosion Rate Measurements

Five papers are included in this section. Two examine the use of guard ring electrodes, one looks at electrochemical impedance spectroscopy, one at a magnetic-based nondestructive technique, and the last paper at techniques to evaluate sealers. It should be noted by the reader that corrosion rate measurements are at best indicative of conditions existing at test time, and given the changes in environment that occur in the field, can vary significantly from day to day or even within a few hours due to changing moisture, temperature, and chloride contents.

Broomfield et al. and Feliú et al. compare the use of guard ring electrodes to conventional counter electrode and reference electrode techniques in determining corrosion rates of steel in field structures. The papers show that the guard ring confines the current to a more well-defined area during polarization resistance so that a more accurate determination of the area polarized can be made. This results in a more accurate representation of the corrosion rate.

Broomfield et al. use the guard ring electrode to evaluate the performance of several rehabilitation techniques that were applied to field structures.

Feliú et al. show that the corrosion rates are significantly lower at low corrosion rates for the guard ring electrode. At higher corrosion rates or with larger counter electrodes the corrosion rate without the guard ring approaches that of the guard ring. It is useful to review the Newhouse and Weyers papers which showed that the guard ring underestimated corrosion rates and the conventional techniques overestimated corrosion rates.

Ghorbanpoor and Shi showed that a magnetic field technique can determine a 3% reduction in cross-sectional steel area. More research is needed with this new application that could offer an additional nondestructive technique that shows cumulative corrosion damage to the time of measurement.

Ford and Mason use electrochemical impedance spectroscopy to examine steel in cement pastes. They use ultra-high frequencies in the MHz range to determine diffusivity and permeability of the paste. Frequencies in the Hz range provide information on the interfacial zone between the steel and paste, and the lower frequencies mHz provide information on passivity. Even though the techniques discussed are more suited for laboratory studies, predictions of permeability from laboratory data might be applicable to estimating service life.

The paper by Whiting and Nagi assesses the performance of penetrating sealers with two new test techniques. One is a resistivity measurement and the other is based upon the absorption of water. Both techniques can be used in the field. Though not a corrosion technique, the evaluation of the condition of sealers over time in the field can be used as a predictor of future corrosion activity due to the ingress of chloride.

Case Studies

Three papers on case studies are given. Two involve marine concrete structures and one is of a corroding ice rink.

Krauss and Nmai provide an initial evaluation of a new fishing pier with an amine and fatty acid admixture to reduce corrosion. They employed visual, chloride, and corrosion potential analyses. They showed that high negative corrosion potential are not indicative of corrosion activity in concrete submerged in sea water and that the initial condition of the structure is good. The importance of developing base-line information for future studies is emphasized.

Sagüés and Powers evaluated the use of spray zinc anodes in several field locations in Florida. They used short embedded rebar probes with switchable connectors so that various cathodic protection parameters could be determined.

Brickey used corrosion potential mapping, chloride analyses, microscopy, and destructive techniques to document and determine the cause of corrosion-induced damage in an ice rink. The paper is useful in showing how to combine multiple techniques to solve a real world problem.

The papers outlined here will give the reader a good background into the latest techniques used in assessing steel-reinforced concrete structures and in modeling future service life based upon the assessment. The reader will also see that considerable work remains in refining techniques to accurately measure corrosion activity. I wish to thank my co-editors Ed Escalante, NIST; Charles K. Nmai, Master Builders, Inc.; and David Whiting, Construction Technology Laboratories, for help in getting speakers, running sessions, reviewing papers, and selecting reviewers. They join me in gratefully acknowledging the efforts of the authors and ASTM personnel that have made this publication possible.

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Grace Construction Products.

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