



# Corrosion Forms & Control for Infrastructure

Victor Chaker, editor



ASTM STP 1137



**STP 1137**

# **Corrosion Forms and Control for Infrastructure**

*Victor Chaker, editor*

ASTM Publication Code Number (PCN)  
04-011370-27



ASTM  
1916 Race Street  
Philadelphia, PA 19103

## Library of Congress Cataloging-in-Publication Data

Corrosion forms and control for infrastructure / Victor Chaker, editor.

(STP ; 1137)

"ASTM publication code number (PCN) 04-011370-27."

"Papers presented at the symposium held in San Diego, CA on 3-4 November 1991"--Foreword.

Includes bibliographical references and index.

ISBN 0-8031-1432-X

1. Reinforcing bars--Corrosion--Congresses. 2. Reinforced concrete--Corrosion--Congresses. 3. Corrosion and anti-corrosives--Congresses. I. Chaker, Victor. II. Series: ASTM special technical publication ; 1137.

TA445.5.C673 1992

620.1'723--dc20

92-35015

CIP

Copyright © 1992 AMERICAN SOCIETY FOR TESTING AND MATERIALS, Philadelphia, PA. All rights reserved. This material may not be reproduced or copied, in whole or in part, in any printed, mechanical, electronic, film, or other distribution and storage media, without the written consent of the publisher.

## Photocopy Rights

Authorization to photocopy items for internal or personal use, or the internal or personal use of specific clients, is granted by the AMERICAN SOCIETY FOR TESTING AND MATERIALS for users registered with the Copyright Clearance Center (CCC) Transactional Reporting Service, provided that the base fee of \$2.50 per copy, plus \$0.50 per page is paid directly to CCC, 27 Congress St., Salem, MA 01970; (508) 744-3350. For those organizations that have been granted a photocopy license by CCC, a separate system of payment has been arranged. The fee code for users of the Transactional Reporting Service is 0-8031-1432-X/92 \$2.50 + .50.

## 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.

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 acknowledge with appreciation their dedication and contribution to time and effort on behalf of ASTM.

Printed in Ann Arbor, MI

October 1992

## Foreword

This publication, *Corrosion Forms and Control for Infrastructure*, contains papers presented at the symposium held in San Diego, CA on 3-4 Nov., 1991. The symposium was sponsored by ASTM Committee G-1 on Corrosion of Metals, Subcommittee G1.10 on Corrosion in Soils, and G1.14 on Corrosion of Reinforcing Steel. V. Chaker, Port Authority of NY and NJ in New York, NY was the Symposium Chairman. Symposium session chairmen were N.S. Berke of W.R. Grace and Co. in Cambridge, MA and E. Escalante of the National Institute of Standards and Technology (NIST) in Gaithersburg, MD.

## About the Cover

The art work is by Melanie Wilson-Ligh of the Port Authority of NY and NJ, New York, NY.

The design concept shows that by using available technology, corrosion of the infrastructure can be controlled and that the life expectancy of both the existing and new infrastructure can be extended indefinitely.

The bottom pictures depict the corrosion impact on infrastructure. The middle pictures represent the state-of-the-art in sensors and computers to help control the corrosion of the infrastructure. The top pictures represent well-maintained infrastructures.

# Contents

<b>Overview—V. CHAKER</b>	vii
<b>Keynote Address—Infrastructure: The Battlefield of Corrosion—E. J. FASULLO</b>	1
<b>Synergistic Effects of Acid Deposition and Road Salts on Corrosion—R. BABOIAN</b>	17
<b>National Cost of Damage to Infrastructure from Highway Deicing—T. R. MENZIES</b>	30
<b>A New Approach to Power-Model Regression of Corrosion Penetration Data— R. H. McCUEN, P. ALBRECHT, AND J. CHENG</b>	46
<b>A Review of Computational Simulation Techniques—V. G. DeGIORGI AND A. I. KAZNOFF</b>	77
<b>Evaluation of an Atmospheric Corrosion Rate Monitor—F. H. HAYNIE</b>	90
<b>Corrosion Control of Weathering Steel Bridges—P. ALBRECHT</b>	108
<b>Wetness Monitoring on the Exterior of Infrastructures—J. J. HECHLER</b>	126
<b>Performance of Rehabilitated/Protected Concrete Bridge Decks—K. BABAEI AND N. M. HAWKINS</b>	140
<b>Utilization of Electrochemical Impedance Techniques to Estimate Corrosion Damage of Steel Infrastructures—K. HOMMA, N. GOTO, K. MATSUOKA, AND S. ITO</b>	155
<b>Improved Rail Fastener Insulation for Stray Current Control—D. GALLER AND P. L. TODD</b>	170
<b>A Theoretical Analysis for the Residual Strength of Corroded Gas and Oil Transmission Pipelines—M. F. KANNINEN, K. V. PAGALTHIVARTHI, AND C. H. POPELAR</b>	183
<b>The NUPIPE® Reconstruction Technology—J. B. HINTE</b>	199
<b>Estimating the Life Cycle of Reinforced Concrete Decks and Marine Piles Using Laboratory Diffusion and Corrosion Data—N. S. BERKE AND M. C. HICKS</b>	207
<b>Investigation of Rebar Corrosion in Partially Submerged Concrete— M. FUNAHASHI, K. F. FONG, AND N. D. BURKE</b>	232
<b>Recent Developments in Inspection Techniques for Corrosion Damaged Concrete Structures—G. JOHN, K. HLADKY, P. GAYDECKI, AND J. DAWSON</b>	246
<b>An Automatic Pipe Corrosion Inspection System—M. SHIMIZU, N. MUKAI, M. HAMADA, AND J. SHIMAMURA</b>	258

<b>Prediction and Control of Sulfide Induced Corrosion in Concrete Sewer Infrastructure and Rehabilitation Techniques—J. K. JEYAPALAN</b>	<b>273</b>
<b>Corrosion Related Deterioration of Reinforced Concrete Structures at Oil Refineries in the Persian Gulf Region—V. NOVOKSHCHENOV</b>	<b>284</b>
<b>Impregnation of Concrete with Corrosion Inhibitors—N. S. BERKE, M. P. DALLAIRE, R. E. WEYERS, M. HENRY, J. E. PETERSON, AND B. PROWELL</b>	<b>300</b>
<b>Predicting Service Life of Concrete Bridge Decks Subject to Reinforcement Corrosion—P. D. CADY AND R. E. WEYERS</b>	<b>328</b>
<b>Measuring the Underground Corrosion of Steel Piling at Turcot Yard, Montreal, Canada—A 14 Year Study—E. ESCALANTE</b>	<b>339</b>
<b>Assessing the Role of Steel Corrosion in the Deterioration of Concrete in the National Infrastructure: A Review of the Causes of Corrosion and Current Diagnostic Techniques—B. H. HERTLEIN</b>	<b>356</b>
<b>Bond Loss Between Epoxy and Alkyd Coated Reinforcement Rebars and Concrete—L. A. MALDONADO, P. CASTRO, J. H. MARRUFO, W. GONZALEZ, AND A. ZAPATA</b>	<b>372</b>
<b>Repair and Cathodic Protection of Corrosion Damaged Reinforced Concrete Wharves in the Middle East—G. JOHN, B. LEPPARD, AND B. WYATT</b>	<b>386</b>
<b>Summary—V. CHAKER</b>	<b>404</b>
<b>Author Index</b>	<b>413</b>
<b>Subject Index</b>	<b>415</b>

# Overview

---

The symposium, Corrosion Forms and Control for Infrastructure was organized to gather the state-of-the-art information in several fields directly related to the corrosion of infrastructure. The accelerated rate of deterioration of this national asset is well recognized. Since the cost of its replacement is prohibitive, its maintenance and the extension of its life expectancy are mandatory. To achieve this goal, new life prediction tools are needed, sensors for testing and monitoring must be developed, and artificial intelligence will have to be used for speed and accuracy.

The papers presented at the symposium and included in this volume met their purpose. The papers covered most of the topics targeted and publicized in the Call For Papers. The topics covered areas such as highway and bridge deterioration, numerical analysis, atmospheric corrosion, electrochemical impedance applications, stray current control, innovative solutions for pipes, corrosion of rebar in concrete, life cycle analysis, sensors for monitoring infrastructure corrosion, and corrosion forms in transportation infrastructure.

This book is useful to both the practicing engineer and the scientists, since it covers numerous practical experiences and applications as well as new concepts for sensors, tools, and computerized techniques. It offers facts and figures for modes of deterioration as well as new solutions for extending the life expectancy of structures. In addition, it gives innovative applications of existing technology to predict and control corrosion of many structures. This book will serve the engineering and scientific community in promoting the use of innovative successful techniques for solving some of the corrosion problems of infrastructure. It will also stimulate the manufacturing community to take some risks in developing needed tools for this important field.

This publication deals with the current problems facing the engineering community, with all its daring challenges. It contains new solutions for current problems and pioneer methodology to avoid future problems. In summary, it could be conceived as the link between the past, present, and future of corrosion control of infrastructure.

## Acknowledgment

The Symposium Chairmen, the Officers, and Members of Committee G-1 on Corrosion of Metals, express their appreciation for the contributions of the authors, the reviewers, and symposium participants. A special acknowledgment of appreciation for the efforts of the ASTM staff in the development, follow up, and delivery of this special technical publication (STP). Some editing was done courtesy of Joan Regen of The Port Authority of NY and NJ, New York, NY.

*Victor Chaker, P.E.*

The Port Authority Of NY and NJ, New  
York, NY; symposium chairman and editor.

ISBN 0-8031-1432-X