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State-of-the-Art Report on Evaluating Cathodic Protection Systems on Existing Reinforced Concrete Structures

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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 requirements or recommendations for general application of this technology, and must not be construed as such.

The purpose of this NACE International technical committee report is to discuss the state of the art information and test methods available to evaluate the effectiveness of cathodic protection (CP) systems used to protect the steel reinforcement of conventionally reinforced atmospherically exposed concrete structures.

This report is intended for engineers and technicians experienced in the application of CP to steel reinforcement in conventionally reinforced atmospherically exposed concrete structures; and by corrosion control personnel concerned with the corrosion of steel reinforcement in aboveground atmospherically exposed concrete structures.

This report does not discuss epoxy coated or galvanized reinforcement or reinforcement composed of any metal other than carbon steel. The test methods discussed in this report do not apply to prestressed and post-tensioned reinforced concrete structures or to underground or underwater reinforced concrete elements or structures.

This report describes the measurement techniques and cautionary measures most commonly used on steel reinforced concrete structures to determine whether a specific criterion has been complied with at a test site. The report includes information only on those measurement techniques that relate to the criteria or special conditions, such as depolarization decay, listed in NACE SP0290.[1]

Scope

This technical committee report provides information regarding test methods for evaluation of the effectiveness of CP systems on conventionally reinforced atmospherically exposed concrete structures in conformance with NACE SP0290, SP0187, and SP0390.[1–3] This report discusses the testing of installed and commissioned CP systems on conventionally reinforced atmospherically exposed concrete structures.

This report was prepared in 2016 by Task Group (TG) 049, "Test Methods for Evaluation of Cathodic Protection Systems on Reinforced Concrete Structures." It is administered by Specific Technology Group (STG) 01, "Reinforced Concrete"; and is sponsored by STG 05, "Cathodic/Anodic Protection"; and STG 62, "Corrosion Monitoring and Measurement." This report is issued by NACE under the auspices of STG 01.

Introduction

This technical committee report provides information about testing procedures typically used to evaluate the effectiveness of CP systems on conventionally reinforced concrete structures as a means to verify compliance with NACE SP0290.

Special conditions in which a given test technique is ineffective or only partially effective sometimes exist. Such conditions may include elevated temperatures and unusual contaminants in the electrolyte. In such situations, corrosion control personnel demonstrate that adequate CP has been achieved.

Conventionally reinforced concrete is a versatile and widely used material and performs very well, provided it does not become contaminated by chlorides or become carbonated by the atmosphere. If the concrete becomes contaminated by chlorides or becomes carbonated, then the natural protective environment surrounding the reinforcement may break down, resulting in corrosion of the reinforcement.

When the natural passive film at the reinforcing steel/concrete interface breaks down as result of contamination of the concrete matrix by chlorides, or if the concrete becomes carbonated, then corrosion of the reinforcement typically occurs. The rate of corrosion is determined by a number of factors such as the moisture content of the concrete, the resistivity, temperature, and oxygen availability at the cathode, and the anode-to-cathode area relationship, as well as other factors.

To arrest corrosion of the reinforcement in conventional reinforced concrete structures, CP has been retrofitted to numerous existing concrete structures world-wide and is now being applied to reinforcement in new structures under construction. The application of CP to conventionally reinforced concrete structures has become an accepted practice to prevent corrosion where the reinforcing steel may be exposed to chlorides or where concrete may become carbonated.

NACE has published a number of standards, state-of-the-art-reports, and test methods for reinforced concrete structures. NACE SP0290 provides criteria for determining the effectiveness of a CP system installed on conventionally reinforced concrete structures.

CP is typically applied by impressed current or by sacrificial anode systems. This report discusses the test methods typically used to evaluate the effectiveness of the CP system.

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Definitions

Cable: A bound or sheathed group of insulated conductors.

Carbonation (of Concrete): A process by which the carbon dioxide of the atmosphere reacts with calcium hydroxide in the concrete pore solution, forming calcium carbonate and reducing the pH of the pore solution in concrete.

Passive Film: At high pH levels at the steel/concrete interface (>12.5), a passive film forms on the steel protecting the steel from corrosion.

Test Lead: A wire or cable attached to a structure for connection of a test instrument to make cathodic protection potential or current measurements.

Tramp Steel: Steel embedded in the concrete matrix that is not intended to form part of the reinforcement and is not electrically continuous with the reinforcement.

Voltage: An electromotive force or a difference in electrode potentials expressed in volts.

Terms not included in the Definitions section may be found in the latest revision of NACE/ASTM[1] G193, "Standard Terminology and Acronyms Related to Corrosion."[4]

Testing of Cathodic Protection Systems

Typical considerations before testing an Impressed Current Cathodic Protection system include the following:
- Design and as-built details, commissioning reports, monitoring reports
- History of the structure and/or CP system as necessary
- Testing plan including access to all parts of the structure and equipment
- System condition, hardware, and software
- Inspection of junction boxes/test stations
- Other embedded test equipment
- Depolarization testing of the structure
- Electrical continuity of anode system
- Alternating current (AC) resistance of anode system
- Electrical continuity of reinforcement
- Visual and mechanical of the structure for delimitations
- Changes and modifications to the cathodic protection system
- Modifications to the structure or elements where cathodic protection has been applied

Typical additional test considerations for impressed current cathodic protection systems include the following:
- Anode condition
- Wiring and conduit condition
- Voltage and current output to each impressed current zone
- Embedded reference to structure potentials on and instant-off
- Surface potential survey of structure
- Inspection of junction boxes/test stations
- Damage to hardware, components or wiring
- Rectifier(s) condition and operation

Additional test considerations for sacrificial CP systems include the following:
- Concrete condition
- Anode condition
- Current output of sacrificial anodes
- Wiring, junction box and conduit condition
- Inspection of junction/test stations
- Damage to hardware, components or wiring

[1] ASTM International (ASTM), 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.