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Electrochemical Realkalization and Chloride Extraction for Reinforced Concrete

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ABSTRACT

This standard addresses corrosion of reinforcing steel in concrete, a serious problem throughout the world in parking structures, bridges and roadways, buildings, sanitary and water facilities, marine structures, concrete pipe, storage facilities, and other structures. This corrosion is directly attributable to the presence of significant amounts of aggressive substances at the steel surface. This standard provides procedures to control corrosion of conventional reinforcing steel in Portland cement concrete structures through the application of chloride extraction or realkalization. These electrochemical techniques are related to the use of impressed current cathodic protection of steel in concrete, as described in NACE SP0290.

KEYWORDS

reinforcing steel, reinforced concrete, realkalization, chloride extraction, corrosion, rebar, cathodic protection.

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Foreword

In NACE standards, the terms shall, must, should, and may are used in accordance with the definitions of these terms in the NACE Publications Style Manual. The terms shall and must are used to state a requirement, and are considered mandatory. The term should is used to state something good and is recommended, but is not considered mandatory. The term may is used to state something considered optional.

This NACE standard practice presents the requirements for electrochemical chloride extraction and electrochemical realkalization of reinforcing steel in atmospherically exposed concrete structures. The standard provides the design engineer and contractor with the requirements for control of corrosion of conventional reinforcing steel in Portland cement concrete structures through the application of chloride extraction or realkalization. This standard is intended for use by owners, engineers, architects, contractors, and all those concerned with rehabilitation of corrosion-damaged reinforced concrete structures.

These electrochemical techniques are related to the use of impressed current cathodic protection of steel in concrete as described in NACE SP0290.[1] State-of-the-art reports on the techniques were previously published by the task group and are available from NACE.[2,3] For more information on design, maintenance, and rehabilitation of reinforcing steel in concrete, refer to NACE SP0187[4] and NACE SP0390.[5]

To provide the necessary expertise on all aspects of the subject and to provide input from all interested parties, Task Group (TG) 054 is composed of corrosion consultants, consulting engineers, architect engineers, cathodic protection engineers, researchers, structure owners, and representatives from both industry and government.

The provisions of this standard should be applied under the direction of a registered Professional Engineer or a person certified by NACE International as a Corrosion Specialist or Cathodic Protection Specialist. His or her professional experience should include suitable experience in corrosion control of reinforced concrete structures.

This standard was prepared in 2007 and revised in 2017 by TG 054 on Reinforced Concrete: Electrochemical Chloride Removal and Realkalization, which is administered by Specific Technology Group (STG) 01 on Reinforced Concrete and sponsored by STG 41 on Electric Utility Generation, Transmission, and Distribution. It is published by NACE under the auspices of STG 01.

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Section 1: General

1.1 Background

1.1.1 Following this General section, this standard is divided into two standalone sections, the first on electrochemical chloride extraction and the second on electrochemical realkalization. This will help the user by ensuring that all the relevant provisions are in one place.

1.1.2 Reinforcing steel is compatible with concrete because of similar coefficients of thermal expansion and because concrete normally provides the steel with excellent corrosion protection. The corrosion protection is the result of the formation of a highly alkaline passive oxide film on the surface of the reinforcement by Portland cement contained in the concrete. This passive oxide film may be compromised by (1) excessive amounts of chloride or other aggressive ions and gases such as carbon dioxide, or (2) the concrete not fully encasing the steel.

1.1.3 Corrosion of the steel occurs as a result of the formation of an electrochemical cell. An electrochemical cell consists of four components: an anode, where oxidation occurs; a cathode, where reduction occurs; a metallic path, where the electrons flow; and an electrolyte (concrete), where the ions flow. The anodic and cathodic areas occur as a result of coupling of dissimilar metals (e.g., reinforcing steel to copper, brass or galvanized fittings or aluminum window frames), exposure to differential environmental conditions, or both. If any one of the four elements of the electrochemical cell is eliminated, corrosion can be prevented.

1.1.4 Corrosion of reinforcing steel in concrete is a serious problem in certain environments throughout the world. This corrosion is directly attributable to the presence of significant amounts of aggressive substances and/or conditions at the steel surface. Parking structures, bridges and roadways, buildings, sanitary and water facilities, marine structures, concrete pipe, storage facilities, and other reinforced concrete structures are being damaged by corrosion. Industry published information indicates that refurbishment and replacement of concrete structures with corroded reinforcement and/or cracking and spalling damage of the concrete costs billions of dollars each year. These losses can be reduced if proper corrosion control factors are considered and addressed during rehabilitation and maintenance repair of reinforced concrete structures.

1.1.5 Carbonation of concrete is a major factor that leads to reinforcing steel corrosion. Carbonation is a process by which atmospheric carbon dioxide reacts with the alkalis in the pore water of the concrete, reducing the pH to near neutral. A carbonation front proceeds through the cover concrete to the reinforcement, where it leads to the breakdown of the passive oxide layer, allowing corrosion to proceed. Electrochemical realkalization can be used to reverse this process and restore the alkaline environment to the reinforcement, preventing further corrosion.

1.1.6 Chloride contamination of the concrete is another major factor that leads to reinforcing steel corrosion. Depending on the environment, it has been shown that chloride ion content as low as approximately 0.2 percent by weight of cement (or approximately 0.6 kg/m^3 [1 lb/yd^3] of concrete, depending on the cement content of the mix) at the steel depth can initiate the corrosion process.[6] Electrochemical chloride extraction (ECE) can be used to move chloride ions away from the steel surface and reestablish the protective passive oxide layer.

1.2 Electrochemical Treatments

1.2.1 Electrochemical treatments for reinforced concrete include cathodic protection (CP), ECE, and electrochemical realkalization (EcR). ECE and EcR are short-term treatments with a temporary installation that is removed after treatment. Treatment is intended to remove the cause of corrosion. On the other hand, CP is a permanent installation.

NOTE: CP of atmospherically exposed steel in concrete is described in NACE SP0290.[1] Many of the practices described in SP0290 are relevant to ECE and EcR in terms of preparation of the structure, testing, and wiring.

1.3 Scope and Limitations

1.3.1 The provisions of this standard shall be applied under the direction of competent persons who, by reason of their knowledge of the physical science and the principles of engineering and mathematics acquired by education and related practical experience, are qualified to engage in the practice of corrosion control on reinforced concrete.

NOTE: The competent person shall have a minimum of ten (10) years of experience in the field of corrosion of steel in concrete and at least three (3) projects similar to the one to be undertaken. They should also be a certified Cathodic Protection Specialist or Corrosion Specialist of NACE International or have an international equivalent qualification or documented equivalent level of education and experience.

1.3.2 The requirements presented here are limited to impressed current ECE and EcR systems for new or existing atmospherically exposed reinforced concrete elements. The provisions of this standard practice are not applicable to prestressed concrete.

1.3.3 Normal reinforcing steel in post-tensioned elements with the post-tensioning strands fully protected in ducts can be treated as long as adequate precautions are taken to ensure that the prestressed steel is not susceptible to hydrogen embrittlement and that it is protected such that the instant off (IR free) potential of the steel does not rise above the hydrogen evolution potential.

Section 2: Electrochemical Chloride Extraction

2.1 Suitability for Treatment

A structure shall be considered suitable for ECE if:

2.1.1 There is sufficient chloride contamination to warrant generalized or localized treatment to retard further chloride attack.

2.1.2 Water ingress can be controlled during treatment so that the current density on the steel can be maintained and accurately monitored, especially in marine conditions. ECE is not suitable for application to the elements of structures in splash tidal and submerged zones.

2.1.3 There is no prestressed steel susceptible to hydrogen embrittlement in the area to be treated. Any prestressed steel shall be monitored to ensure that its instant off (IR free) potential does not go more negative than –1,100 mV vs. a copper/copper sulfate reference electrode.