NACE TR01105-2020
Item No. TR01105-2020
Revised: 2020-08-19
Approved: 2005-03

Sacrificial Cathodic Protection of Reinforced Concrete Elements—A State-of-the-Art Report

This NACE International technical committee report represents a consensus of those individual members who have reviewed this document, its scope, and provisions. Its acceptance does not in any respect preclude anyone from manufacturing, marketing, purchasing, or using products, processes, or procedures not included in this report. Nothing contained in this NACE report is to be construed as granting any right, by implication or otherwise, to manufacture, sell, or use in connection with any method, apparatus, or product covered by Letters Patent, or as indemnifying or protecting anyone against liability for infringement of Letters Patent. This report should in no way be interpreted as a restriction on the use of better procedures or materials not discussed herein. Neither is this report intended to apply in all cases relating to the subject. Unpredictable circumstances may negate the usefulness of this report in specific instances. NACE assumes no responsibility for the interpretation or use of this report by other parties.

Users of this NACE report are responsible for reviewing appropriate health, safety, environmental, and regulatory documents and for determining their applicability in relation to this report prior to its use. This NACE report may not necessarily address all potential health and safety problems, or environmental hazards associated with the use of materials, equipment, and/or operations detailed or referred to within this report. Users of this NACE report are also responsible for establishing appropriate health, safety, and environmental protective practices, in consultation with appropriate regulatory authorities if necessary, to achieve compliance with any existing applicable regulatory requirements prior to the use of this report.

CAUTIONARY NOTICE: The user is cautioned to obtain the latest edition of this report. NACE reports are subject to periodic review, and may be revised, or withdrawn at any time without prior notice. NACE reports are automatically withdrawn if more than 10 years old. Purchasers of NACE reports may receive current information on all NACE publications by contacting the NACE FirstService Department, 15835 Park Ten Place, Houston, TX 77084-5145 (tel: +1 281-228-6200, email: firstservice@nace.org)

ABSTRACT

This technical report presents state-of-the-art information on several commercially available galvanic cathodic protection/prevention systems for protecting atmospherically exposed reinforced concrete structures. The information contained in this report has been provided by key manufacturers of these systems and is intended as a technical resource for engineers responsible for the rehabilitation of reinforced concrete structures. It may also be useful to owners, contractors, and other practitioners related to the field of galvanic cathodic protection (CP). All information related to galvanic CP is intended for atmospherically exposed concrete structures and may not be applicable to concrete containing epoxy-coated reinforcing steel, galvanized, or other coated or nonferrous reinforcement..

KEYWORDS

Cathodic protection, galvanic, sacrificial anode, reinforced concrete, metallized coating, TG 557.

Foreword

The purpose of this technical committee report is to present state-of-the-art information on several commercially available galvanic cathodic protection/prevention systems for protecting atmospherically exposed reinforced concrete structures. A summary of these systems is presented in Appendix A. It is beyond the scope of this report to fully address all factors associated with design, criteria, implementation, quality control, cost, maintenance, and monitoring of these systems. The information contained in this report has been provided by key manufacturers of these systems and is intended as a technical resource for engineers responsible for the rehabilitation of reinforced concrete structures. It may also be useful to owners, contractors, and other practitioners related to the field of galvanic cathodic protection (CP). All information as it relates to galvanic CP is intended for atmospherically exposed concrete structures and may not be applicable to concrete containing epoxy-coated reinforcing steel, galvanized, or other coated or nonferrous reinforcement. Galvanic CP has also been successfully applied to buried or submerged reinforced concrete structures; however, this aspect is not addressed in this state-of-the-art report.

This NACE technical committee report was originally prepared in 2005 by Task Group (TG) 047 on Sacrificial Cathodic Protection of Reinforced Concrete Elements, which was administered by Specific Technology Group (STG) 01 on Reinforced Concrete and sponsored by STG 05 on Cathodic/Anodic Protection. It was revised in 2020 by TG 557 on Sacrificial Cathodic Protection of Reinforced Concrete Elements. TG 557 is administered by STG 01 and sponsored by STG 05. This report is issued by NACE International under the auspices of STG 01.

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.

Sacrificial Cathodic Protection of Reinforced Concrete Elements—A State-of-the-Art Report

Tables and Figures

Introduction

Over the past several decades, the corrosion of steel reinforcement embedded in concrete structures has received considerable worldwide attention. In theory, concrete and reinforcing steel are very compatible. They have similar coefficients of thermal expansion. Concrete, because of its highly alkaline nature, creates a protective environment for the steel. Studies have shown that corrosion activity and damage result when critical quantities of aggressive substances penetrate through the concrete pore structure by diffusion and other transport processes and reach the embedded steel reinforcement. When this happens, the naturally occurring passive film developed by highly alkaline concrete becomes contaminated with aggressive ions, eventually breaking down this protective layer. In regions of low electrical resistance, aggressive ions, mostly in the form of salts, attack the passive film and develop localized anodic sites (pits) on the surface of the steel. Immediately adjacent to these anodic sites are oxygen-rich regions that cathodically "fuel" the corrosion reaction. As corrosion proceeds, the lower pH in and around the anodic sites attacks the passive layer in greater proportions, facilitating corrosion propagation. These corrosion products occupy more volume than the reactant steel, so pressure builds until the tensile force required to confine the corrosion product exceeds the capacity of the concrete cover and the concrete cracks.

Several approaches have been used to rehabilitate concrete structures suffering from corrosion damage. The most widely used approach typically involves removing the damaged concrete in and around the affected area and replacing it to the original dimension. The principal intent of this remove-and-replace approach is to return the form and function of the structure. Although this strategy is widely used, it rarely incorporates the complete removal of contaminated areas that surround the damaged region, often resulting in a short-term solution. Modifications to this technique include expanding the area excavated to include sound but chloride-contaminated or carbonated concrete, expanding the repair to include areas where the steel-reinforcement potential is more negative than a defined threshold, or inclusion of discrete anodes in the repair.

The remove-and-replace approach is normally broken into two general categories. The first is patch repair, and the second is rehabilitation. Patch repair is a short-term solution that makes no attempt to extend the structure life, but merely restores concrete back to dimension. The rehabilitation technique attempts to return the distressed area in uniformity with the pre-existing conditions. The rehabilitation technique carries with it some expectation of an increase in service life. In some applications, a coating is applied to the reinforcing, galvanic anodes are tied to the reinforcing in the patch area, and/or a corrosion inhibitor is included either as an additive to the repair/replacement concrete mix or as a post treatment. The methods of concrete repair are much more involved than discussed in this report and are well integrated into most structure owner agencies and the civil engineering community. The reader should refer to American Concrete Institute[1] or International Concrete Repair Institute[2] standards and guidelines for more detailed discussion of concrete repair practices.

Alternatively, cathodic protection (CP) applies electrochemistry to halt the corrosion process or reduce it to levels below engineering significance. Cathodic protection is an electrochemical technique used to reduce the corrosion of metallic materials. This is accomplished through the addition of sufficient cathodic current to the metal-electrolyte system to counteract the anodic current produced by the electrochemical corrosion reaction. Providing cathodic current increases the rate of the cathodic reaction (the formation of hydroxide [OH^-] and possibly hydrogen [H_2] on the metal being protected, while decreasing the rate of the anodic reaction (metal dissolution). If enough cathodic current is applied, the entire reinforcement network becomes the cathode and corrosion propagation is halted. The source of this cathodic current is immaterial to the protection process, and can come from impressed current, or galvanic sources.

Definitions

The definitions of many of the corrosion-related terms used in this report can be found in NACE/ASTM[3] G193.[1] Other terms not included therein that have been used in this report are defined as follows:

Cathodic Prevention: The application of cathodic polarization to passive steel to prevent or delay a transition to the actively corroding condition.

Humectant: A substance that promotes retention of moisture.

Near-White Metal Appearance: A cleaned surface from which all oil, grease, dirt, mill scale, rust, corrosion products, oxides, paint or other foreign matter have been completely removed from the surface except light shadows.

[1] American Concrete Institute (ACI), 38800 Country Club Dr., Farmington Hills, MI 48331-3439.
[2] International Concrete Repair Institute, Inc. (ICRI), 1000 Westgate Dr., Ste. 252, St. Paul, MN 55114.
[3] ASTM International (ASTM), 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.