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Influence of Hot-Dip Galvanizing of Reinforcement on the Kinetics and Thermodynamics of Corrosion Process in Concrete

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Abstract

This work is an interdisciplinary study which combines reinforced concrete construction domain with analytical techniques, specific for electrochemistry. This paper presents a synthesis of research in this field and own experimental results. The aim of the research was to highlight, both in terms of thermodynamic and kinetic, the enhanced corrosion resistance hot dip galvanized reinforcement embedded in concrete, compared with the steel reinforcement anticorrosive unprotected. The experimental researches were conducted during the concrete curing. In parallel, it was analyzed the reinforcement corrosion, in embedding conditions in a concrete with Cl^- content, artificially induced. The experimental results showed the efficiency of the corrosion protection obtained through galvanizing: the slowing of the corrosion process and the endurance probability of a higher chlorine concentrations till to the initiation of corrosion.

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1. Introduction

Worldwide, it is an increasing tendency regarding the implementation of the concept of sustainable development in all fields. In concrete construction field, the hot dip galvanizing can be a partner in this goal, because of the efficient corrosion protection that it pro-vides to the reinforcement and the increasing of structures life. The conducted research, till now, have shown a high corrosion resistance of embedded reinforcement in concrete,

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especially in chlorides attack conditions, especially if it was previously heat galvanized. ZQ Tan [1], SR Yeomans [2], Andrade [3, 4], Sistonen [5, 6], and others, have shown that the heat galvanizing process of reinforcement does not replace the use of an appropriate quality concrete, but can increase the life of concrete structures with 70-100 years and that the chloride concentration in concrete, which the reinforcement can withstand without galvanized reinforcement corrosion initiation, is 2.5 - 4 times greater than that for the unprotected reinforcement corrosion, with a cost increase of only 0.5-3% of the total costs of a project.

The hot dip galvanizing of steel reinforcement is done routinely in an industrial technological process. After this process, on the steel surface, it forms a layer of Zn and Zn-Fe alloys, intimately linked of the steel substrate through the so-called metal bonds, Figure 1.

In the alkaline environment of the concrete, the zinc layer of the steel reinforcement protects the steel through two mechanisms: through pellicular protection, preventing the corrosive agents to penetrate till to the reinforcement surface of the steel substrate, and through cathodic protection, due of the role zinc which plays, as an anode in the couple Zn / steel: it corrodes instead of steel which becomes the cathode, Figure 1 [1,2,3,4,5,6,7].

Arliguie [8] showed that when introducing the hot dip galvanized steel reinforcement in fresh concrete, its corrosion potential is set at -1400 mV (SCE) and moving toward more positive values during the hardening concrete. After about five hours after embedding, the research literature has shown that are fulfilled the conditions of zinc passivation. After these reactions, the zinc layer thickness is reduced with approx. 10 micrometers. Based on experimental results, ZQ Tan [1] indicated that the thermally zincated reinforcement corrodes in the first 9-10 hours of the embedding in concrete, during which there is a maximum corrosion current saddle 90 μA/cm2 and a corrosion potential ranging from -1.4 V to -0.7 V (SCE), after which it passivates. Tittarelli and Bellezza [7] indicated a corrosion potential of -1350 mV registered immediately after the contact of reinforcing concrete with hot dip galvanized steel, potential which moves, in about 6 hours, to values of -750 mV SCE) for concrete with water / cement ratio 0.45 and to values of -600 mV (SCE) if the water / cement ratio is 0.75.

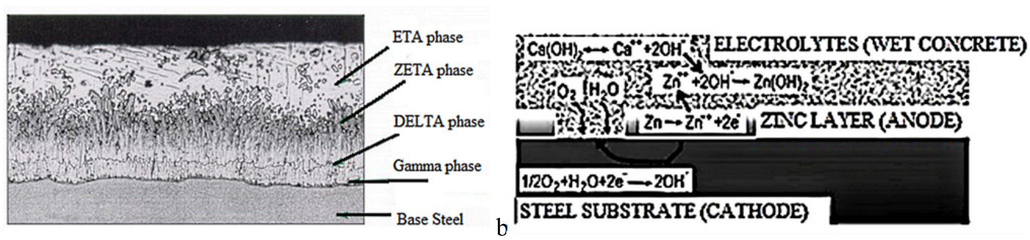

Fig. 1. a) Reinforcement zinc coating structure [1], b) Cathodic protection mechanism scheme offered by zinc steel reinforcement [6]

As a result of the activation of zinc in highly alkaline environment of fresh concrete, it reacts with the calcium and it occurs the formation of calcium hidroxizincat $CaZn(OH)_3)_2*2H_2O$ [1, 2, 3, 4, 5, 7, 9, 10, 11, 12, 13, 14]. This corrosion product has on the one hand, passive properties and on the other hand facilitates the adhesion between the reinforcement and concrete because of needle crystals that grow and diffuses into the matrix of concrete, anchoring the hot dip galvanized reinforcement in the cement grout from the immediate vicinity. The formation of calcium hidroxizincat passive layer (CHZ) was highlighted by Carbucicchio et al. [15], Haran et al. [16], Liebau [17], Proverbio et al. [18] and Andrade Macias [19], ZQ Tan [1], Maahn [20], Tittarelli and Bellezza [7] and Yeomans [2].

The formation mechanism of calcium hidroxizincat is not fully clear. In literature, they have proposed a number of mechanisms.

According to Liebau [17] the mechanism is based on the following reactions:

$$Zn + 2H_2O \leftrightarrow Zn(OH)_2 + H_2 \quad (1)$$
$$2Zn(OH)_2 + 2H_2O + Ca(OH)_2 \rightarrow Ca(Zn(OH)_3)_2 * 2H_2O \quad (2)$$

Yeomans and Andrade [3, 2] propose the following chemical reactions: