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Evaluation of Resistance of Intermetallic Fe-Zn Coating in the Model Environment as Concrete Pore Solution

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Abstract

Article assesses the effectiveness of intermetallic Fe-Zn coating on steel elements due to their potential application in concrete structures. Introduction part of this article summarizes corrosion behavior of hot-dip galvanized steel in fresh and aged concrete with focusing on corrosion resistance intermetallic Fe-Zn (especially ζ phase-FeZn₁₃). Resistance of unconventional Fe-Zn coating created on the steel was tested in model pore solution of concrete. Results were evaluated by the time flow of spontaneous corrosion potential and polarization resistance. Based on the measured data we can say that the Fe - Zn - (Al) coating has a similarly low resistance in an alkaline environment like coatings obtained with conventional hot-dip galvanizing process.

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Keywords: Fe-Zn coating; steel; concrete; pore solution; corrosion potential; polarization resistance.

1. Introduction

Coating the surface of carbon steel reinforcement or other components designed for use in concrete (sliding pins, ground anchors, iron wires, etc.) can extend the life of the entire structure. It is important to introduce corrosion protection, especially where there is a high likelihood of chloride anions from salts, such as NaCl or CaCl₂. Reinforced concrete structures near highways or other intersections (bridges, tunnels, etc.) or those in contact with salt water (e.g. piers) are primarily vulnerable. Chloride anions diffuse through water in the capillary system of the

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concrete and cause activation and subsequent corrosion of the reinforcement and an unacceptable corrosion rate [1]. The result is the thinning of the diameter of the reinforcement and also the destructive expansion of steel corrosion products. The final effect is the need to perform remedial countermeasures for these structures [2,3].

Suitable non-porous coatings cannot prevent this occurrence, but can delay the time until activation of the steel and thus considerably extend the life of structures. For economic, historical and technological reasons coatings of organic origin (epoxies, coatings based on copolymers of polyethylene, PVC) or coatings formed by conventional galvannealing process are discussed in this context [4].

There are questions about the suitability of zinc coating for protecting steel in concrete. In older literature, the zinc coatings are frequently referred to as beneficial in protecting steel in concrete under the influence of chloride anions. At present the view of the application of hot-dip galvanizing and reinforcement elements into concrete is changing. The reason for this is the demonstrated instability of the coating in fresh concrete where there is excessive corrosion activity due to hydrogen evolution. Coating damage due to initial corrosion in concrete correlates with a negative impact on its resistance to chlorides. There are also legitimate concerns that releasing hydrogen increases the porosity of fresh cement paste. This fact reflects negatively on cohesion of coated reinforcement with concrete. Both factors reduce the total loading capacity of reinforced structures [5,6].

The literature lacks a clear description of the behavior of intermetallic phases of Fe-Zn in the alkaline environment of concrete. It is believed that increased resistance is due to the presence of iron in their structure. Namely steel corrodes in fresh concrete in a passive state at a negligible corrosion rate. While zinc has low resistance in an alkaline environment, it unequivocally provides increased resistance to chloride [7].

Also in cases where this is compared to the corrosion resistance of galvanized steel with an external layer of FeZn₁₃ (due to the increased content of Si in galvanized steel - Sandelin -effect "Grey Galvanizing" [8]) and the external layer Vol substantially pure zinc (eta phase - "Bright Galvanizing"), the environment in real concrete indicates inferior corrosion resistance of the intermetallic phase. In the tests, while in both cases evolution of hydrogen was observed in the concrete, in the case of external intermetallic phase FeZn₁₃ showed significantly lower hydrogen overvoltage (i.e. easier elimination of hydrogen). Additionally, it was shown that inhibiting hydrogen evolution at this stage in the real environment of the concrete cannot be realized via chromate conversion surface treatment [9]. The lower corrosion resistance of intermetallic Fe-Zn compared to pure zinc in real concrete has been confirmed by other studies [4,10,11,12]. In addition, similar results can be seen even when testing the resistance of intermetallic Fe-Zn (formed by alloying Zn) in model porous concrete solutions [13]. The lower stability of intermetallic phases of Fe-Zn compared to pure zinc was confirmed in the solution with the addition of NaCl [14,15]. According to the results of other work, a coating comprising various intermetallic Fe-Zn has better or at least equivalent resistance to the coating in a wide range of corrosion tests (no test in real concrete or concrete simulating real environments) [16-18].

The article assesses the composition, thickness, and corrosion resistance of the intermetallic coating in an alkaline medium simulating real concrete. The coating was formed on steel using a modified diffusion galvanizing process.

2. Method

Samples of coated steel (dimensions 100 x 75 x 3 mm, Fig. 1) have been segmented for x-ray fluorescence analysis (XRF), x-ray diffraction (XRD) analysis and metallography of the coated sample cross-section. The objective of these analyses is to check the elemental composition of the coating, the exact composition of intermetallic phases, and determine thickness and compactness. XRF was carried out using the PANalytical Axios equipment and OMNIAN evaluation software. XRD was carried out using the PANalytical XPert PRO equipment and High Score Plus evaluation software. Images coating appearance were recorded on an ARSENAL AM2-T optical microscope and the cross-cut was observed under an OLYMPUS PME 3 microscope [8].

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