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Measurements on corrosion rate of reinforcing steel under various environmental conditions, using an insulator to delimit the polarized area

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Abstract

This paper presents measurements of corrosion rate of reinforcement by means of the original method involving delimitation of the polarized area with an insulator. This method consists of a typical potentiostat connected with a three-electrode setup, in which a circular electrode used as the auxiliary electrode is placed on the surface of concrete, and the polarized area is delimited by making a notch along the whole thickness of concrete cover. The notch, finally filled up with resin, is ring-shaped with a diameter slightly larger than the diameter of the counter electrode. The results of this method were verified by conducting measurements in an aqueous extract from crushed concrete, with LPR and EIS methods. Its properties were modified to map various environmental conditions, e.g. strongly carbonated concrete, concrete saturated with chlorides, or concrete with satisfactory protective properties to reinforcement. Each of three extracts contained a polished rebar, and auxiliary electrodes – circular and rectangular (with its side length equal to rebar length) in shape. A ring insulator was modelled with a fragment of the plastic tube. The comparative analysis of results obtained for partial polarization process by a circular electrode, with and without the insulator impact; and for the complete polarization by a counter electrode, revealed effectiveness of the proposed method under various environmental conditions. Electrical simulation was used to explain the effect of delimiting polarized area of rebar.

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Keywords: reinforced concrete structures, reinforcing steel, polarization resistance method, electrochemical impedance spectroscopy

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1. Introduction

In-situ measurements of corrosion rate of reinforcement in concrete structures involve more and more advanced electrochemical methods, from Linear Polarization Resistance LPR [1], Galvanostatic Pulse GP [2], to advance measurements by means of Electrochemical Impedance Spectroscopy EIS [3,4]. Each of those methods includes a three-electrode setup connected with a potentiostat, in which a rebar is used as the working electrode, a conductor (usually a metal disk resistant to corrosion) is used as the auxiliary electrode, which together with the reference electrode is placed on concrete surface. The auxiliary electrode in *in-situ* tests has considerably smaller area than large reinforcement. The resulting disproportion causes a non-uniform flow of current between electrodes during the tests. A range of current impact (known as polarization range) decreases as a distance to the counter electrode increases. Its value is influenced by concrete resistivity (which mainly depends on its moisture content), and predominantly by reinforcing steel resistance which increases as corrosion processes develop in steel. As the polarized area is a variable and unspecified value, many attempts are made to estimate or delimit this area to the already specified range. The defined polarized area is required to calculate properly corrosion rate.

The polarized area is estimated by means of two [5] or more counter electrodes [1] of different sizes (Fig. 1a). Such methods assume the constant nature of non-uniform current flow which amounts to constant value L_{crit} adopted regardless of the counter electrode size. Subsequent measurements using the counter electrodes *1* with increasing length L_i p produced $R_{p,i}$ values (related to increasing surface of the tested bar– $A_{WE,i} = \pi\phi(L_i + 2L_{crit})$. By defining the function of $R_{p,i}$ which depends on the polarized area $A_{WE,i}$ (Fig. 1b), it is extrapolated to the quasi-infinite surface area $A_{WE,\infty}$, at which $R_{p,\infty}$ value is near real R_p value.

On the other hand, delimiting the tested area of polarization is the most advanced technique requiring the additional auxiliary electrode *2*, so called a “guard ring” [6]. The additional electronically-controlled electrode *2* delimits current flow from the main auxiliary electrode to the defined area (Fig. 1c).

None of those methods is yet universal. The method of evaluating the polarized area is insufficient in case of localized corrosion. The “guard ring” method is less effective if reinforcement is slightly corroded or shows no signs of corrosion. Moreover, it requires more advanced equipment.

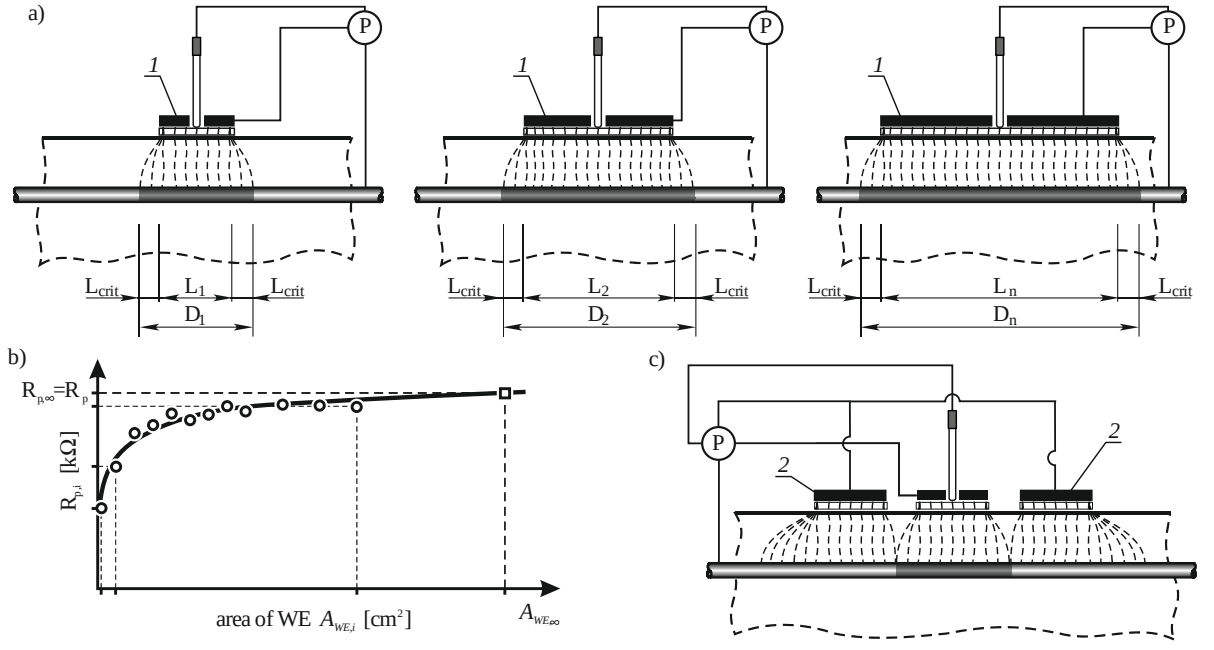

Fig. 1. Methods of controlling or estimating the tested reinforcement area during electrochemical measurements – described in the text.