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Evaluation of maximum and minimum corrosion rate of steel rebars in concrete structures, based on laboratory measurements on drilled cores

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Abstract

This paper presents a method of conducting diagnostic tests for corrosion rate in concrete structures, which has been patented by the authors. The method consists in drilling cores with embedded pieces of steel reinforcement from cylindrical structures, and arranging a three-electrode system on such cores to measure polarization with a potentiostat. The three-electrode arrangement uses a piece of steel reinforcement in concrete core as the working electrode, a stainless steel sheet placed on one of the core bases – as the counter electrode, and an electrode of constant and known potential as the reference electrode. Determining the maximum and minimum corrosion rate of a steel bar in the concrete core is the most important element of the developed method, in which changeable temperature and humidity conditions are modelled around the tested structure. Extremely adverse and highly favourable values of temperature and humidity are determined for individual tested structures. Those parameters can be monitored in a climatic chamber while measuring polarization resistance of the reinforcement. This paper also includes examples of practical application of this method in diagnostic tests conducted by the authors on responsible reinforced concrete structures

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Keywords: concrete structures; reinforcing steel; corrosion rate; diagnostic methods; concrete cores; electrochemical polarization, LPR; EIS

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1. Introduction

This paper addresses problems on advanced diagnostic techniques [1÷5] and monitoring [6, 7] of corrosion in responsible reinforced concrete structures. Both diagnostic techniques and corrosion monitoring of reinforced concrete are fundamentally based on two groups of test methods. The first group includes electrochemical measurements (e.g. Linear Polarization Resistance [8] /LPR/, Galvanostatic Pulse [9] /GP/, or Electrochemical Impedance Spectroscopy [10] /EIS/) to evaluate the intensity of corrosion processes of reinforcement. Tests on concrete protective properties to reinforcement, used to determine causes of corrosion (chloride content in concrete, pH measurement of concrete pore solution) are classified into the second group of test methods.

Corrosion rate of reinforcement in concrete is the valuable information which can be gained from electrochemical polarization measurements. The corrosion rate indicator of reinforcing steel $CR = 0.0116\ i_{corr}$ was proportional to corrosion current density i_{corr} which could be determined only if the tested surface area of reinforcement A_p was known. As during the measurements, there was no direct access to tested rebars protected with the cover, the correct interpretation of the test results was a complex process with potentially substantial errors. The published literature describes only few testing techniques that consist in polarization methods (LPR, EIS, GP) and can be used to estimate the polarized area A_p of reinforcement, and consequently, to determine the corrosion rate indicator *CR*.

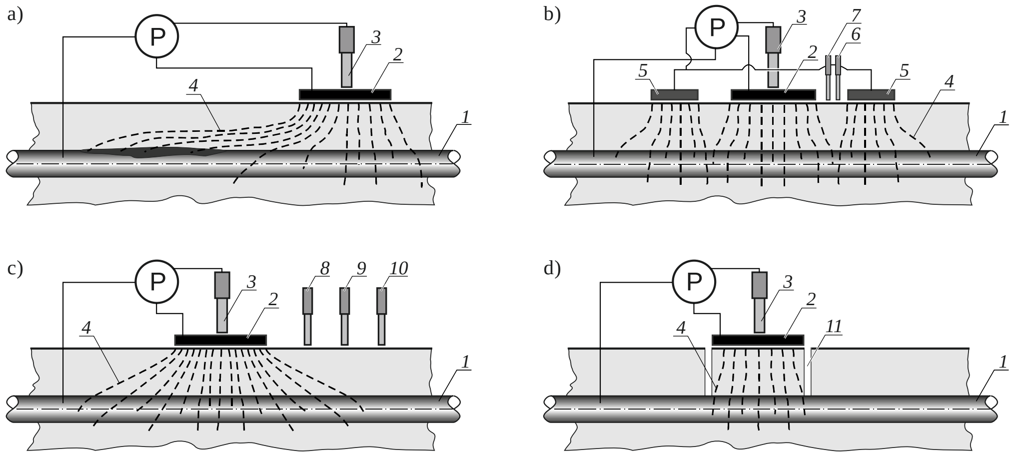

Fig. 1. Measurement techniques for diagnosing corrosion of reinforced concrete structures: (a) a unguarded counter electrode method [11]; (b) a guard ring method with auxiliary reference electrodes [2, 8]; (c) a potential attenuation method [12]; (d) a method of ring insulator [13, 14]

Each diagnostic test of reinforced concrete corrosion involving measurements of reinforcement polarization resistance, requires a three-electrode setup (Fig. 1a). It consists of reinforcement as a working electrode *1*, a counter electrode *2* and a reference electrodes *3* placed on concrete surface. The measuring setup illustrated in Fig. 1a is the simplest, and at the same time the most disputable solution due to boundless flow of polarizing currents *4* over the surface of tested reinforcement (Fig. 1a) [5, 11, 15, 16]. An additional external circular counter electrode *5* (Fig. 1b) in the sensor ensures a stricter control over the polarized area [2, 8, 17]. Two additional reference electrodes *6* and *7* (Fig. 1b) in the sensor considerably improve the correct determination of polarized area of the reinforcement due to effective modulation of polarizing currents [18]. However, concentrated and/or multi-layer reinforcement of the tested structure may cause some interpreting problems. Less common is a multiple electrode, also known as potential attenuation method [12] (Fig. 1c). This method makes use of a sensor consisting of five electrodes: a circular counter electrode *2*, a reference electrode *3* in the central location, and three auxiliary reference electrodes *8, 9, 10* placed along an axis of the tested rebar. Potential values over the rebar length can be controlled, and thus the polarized area can be determined, by arranging properly reference electrodes. This method can be successfully used for a single rebar. However, close proximity to other rebars makes the results less reliable. In the paper [19], the possibility of using electrodes of large surface area (>1000 cm^2) to test corrosion rate of reinforcement was analyzed. However,