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Simultaneous effect of nano and micro silica on corrosion behaviour of reinforcement in concrete containing cement strength grade of C-525

Hamid Eskandari-Naddaf[a,]*, Ali Ziaei-Nia[a]

Department of Civil Engineering, Hakim Sabzevari University, Sabzevar, Iran.

Abstract

The present study investigated the changes in the effect of additive nano-silica replacing micro-silica to reduce corrosion rate of steel in the concrete made of C-525 cement in a corrosive environment, and also the optimum combination of these additives in reinforced concrete for the production of reinforced concrete with high resistance to corrosion of the reinforcement. To this end, 7 series of cylindrical corrosion samples were prepared, which comprised a base design and 6 designs of various combinations of micro and nano silica, weighing a constant 11% in total of the weight of cement used in each sample. Samples were placed in a 3.5% salt-water solution and underwent various electrochemical tests, including corrosion potential (OCP), linear polarization (LPR), impedance spectroscopy (EIS), and Tafel polarization test. The results obtained suggested combined use of 1.6% nano and 9.4% micro-silica for achieving the most appropriate cost considering the increased useful life of concrete structures and the optimum reduction in rate of corrosion of concrete.

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Keywords: Concrete, Corrosion, Electrochemical methods.

* Corresponding author. Tel.: +98-514-401-3386; fax: 98-514-401-2789.
E-mail address: Hamidiisc@yahoo.com

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1. Introduction

According to The need for manufacturers in different parts of the world to produce concrete with higher corrosion resistance to build structures in exposed to corrosive ions at optimal cost, minimum damage to the environment, requires materials that are usually available everywhere. Caused by exposure to chloride ions is considered the main destructive factor in reinforced concrete structures [1-5]. The ability of a substance to resist displacement of ions usually depends on electrical resistivity, and inversely proportional to concrete resistivity [6]. Researchers have demonstrated that concentration of corrosive materials and environmental conditions [7], percentage of micro-silica [8] and nano-silica [9] additives can reduce corrosion in concrete [10]. The interest in these additives is because of their advantages over other corrosion protection methods including diversity in type and amount and lower costs [11, 12]. Although the effects of micro and nano silica in increasing corrosion resistance of ordinary concretes is well-known [13], their combined effects and optimum amounts have not yet been studied. Moreover, since these tests are non-destructive, performing several different electrochemical corrosion tests plus one destructive test in a chloride medium, instead of a single test, will produce better and more acceptable results and different parameters for identifying potential and rate of corrosion [14, 15].

It should be noted that in the research conducted on the combination of micro and nano silica binary at different doses in the manufacture of concrete with cement 525 with the aim of reducing the corrosion rate from chlorine ion and reaching their optimal consumption together they are not used. For this purpose, 3 non-destructive tests (corrosion potential OCP; linear polarization LPR; and impedance spectroscopy EIS) and Tafel polarization destructive test were carried out on 7 series of test samples, so that different dimensions of the effects of these additives can be accurately studied and compared.

2. Experimental

2.1. Materials properties and mixture proportions

To perform the corrosion test, seven 100 × 150 mm cylindrical concrete samples reinforced with 18Ø ribbed polished steel bars were exposed to salt ion attack, such that 70 mm of the steel bar length was placed in the middle of cylindrical samples (epoxy-free) and was tested after the standard 90 days curing age. Portland cement II-525 kg/cm^2 of standard specification [16], and river-type aggregate of 9 mm maximum diameter, with standard poly-carboxylic superplasticizer [17] were used. Nano-silica (NSF) of 20gr/cm^3 density was used as an emulsion suspended-in-water, with 29.6-31% silica, pH of 9.6-10.2, maximum viscosity of 7, and specific area of 200-240 m^2/gr. Micro-silica powder (MSF) of specific area 20-25 m^2/gr, was used as spherical particles of 229 nm diameter and amorphous structure according to standards [18].

Samples were made from cement grade 350 kg/m^3, W/C = 0.44 and superplasticizer weight 0.36% of cement weight. Total percentage weight of MSF and NSF mixture in each sample was 0.11 of weight of cement used, which was within the range recommended by some researchers as the appropriate amount of micro-silica for enhancing certain endurance properties of concrete [19]. Mix 1 (control mixture) was prepared without nano or micro silica. The difference in mixture designs was in the proportion of additives used, such that in mix2 to mix7 designs, the following percentages of NSF and MSF were respectively used: (0.111, 0.0), (0.095, 0.016), (0.079, 0.032), (0.055, 0.055), (0.032, 0.079), and (0.0, 0.111).

3. Methods

First, to find natural corrosion potential of samples according to standards [20], OCP test was performed at temperature of 25 °C, using a potentiostat (model ACM Instrument-Gill AC) and platinum counter electrode of 2 cm2 area in 3-electrode method.

Then, samples were subjected to Linear Polarization Resistance (LPR) test with DC current and potential sweep range on from -10 mV cathode surface to +10 mV anode [21] compared to corrosion potential found in OCP test. Next, current was found from resistance using Stern-Geary equation [21-23]. The corroded mass and ultimately corrosion rate were found according to ASTM G102-89 standard and Faraday's current law [10, 23].