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Testing sodium silicate as corrosion inhibitor for construction steel

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Extended Abstract

1 Introduction

Corrosion inhibitors are regularly used to minimize corrosion progress in reinforced concrete. Many inorganic inhibitors have been tested. Nitrite ions are very effective but not environmentally friendly since they can leach and contaminate the surrounding soil and water [1-3]. Among other inorganic ions have shown promising results, silicate ions are of particular interest due to their low cost and low toxicity. While promising results have been reported in pore-simulating solutions, there is little information in the literature where silicate ions in mortar or cement pastes are evaluated as corrosion inhibitors [4, 5]. The purpose of this study is to evaluate the effectiveness of silicate ions as carbon steel inhibitors when they are tested in mortar.

2 Materials and Methods

Tests were carried out including reinforcement bars (rebars) in a mortar (see Figure 1). The mortar was prepared with a water/Portland cement ratio of 0.6 and sand/cement ratio equal 3 [6]. Mix R had no admixed inhibitor and mix S incorporated $Na_2SiO_3.5H_2O$ using a 0.3 mol/L solution to replace the water in the mix. After being cured, a group of mortars R was immersed in silicate ions solutions 24 h (R-S24h). Then, mortars were immersed in aerated 0.3 mol/L NaCl solution for 8 months and were periodically evaluated by Electrochemical Impedance (EIS) and Polarization Resistance (Rp). Cylindrical mortar specimens (4.5 cm in diameter and 9 cm in length) were also prepared following ASTM C-39 standard [7] to characterize the mechanical properties of the mixes. Compressive strength and porosity following ASTM C-642 standard [8], were evaluated after 2 days of setting and 7 days of curing the specimens. The alkaline reservoir in the mortar (content of insoluble $Ca(OH)_2$) was investigated by a lixiviation test using Phenolphthalein and Yellow Alizarin to verify the final pH after the lixiviation process (15h of boiling in tap water).

3 Results

Table 1 presents the evolution of the open circuit potential and Rp values over the 240 - day exposure period. Polarization resistance values (Rp) were calculated from linear potential sweeps. The values were corrected (Rp*) by subtracting the mortar resistance (R_M), calculated from EIS results. Also, electrochemical parameters after fitting EIS

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results (see Figure 2) are presented in Table 1. After the first 15 days, Rt and Rp* values lower than 50 kΩ cm^2 were recorded for mix R and mix S. However, Rt and Rp* values higher than 50 kΩcm^2 were measured for R-S24h after 240 days of exposure.

Figure 1 - Schematic representation of the mortar samples under analysis

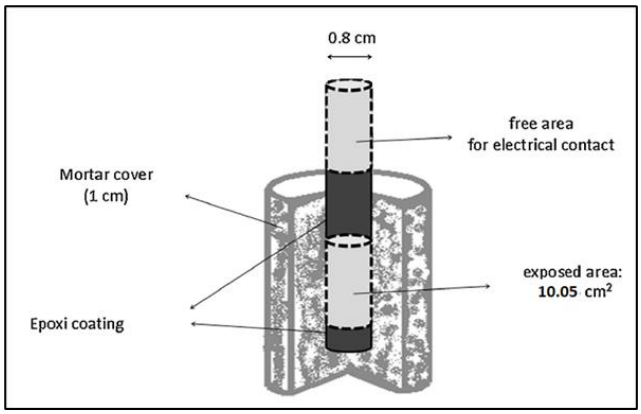

Figure 2 - Equivalent circuit used to analyze the impedance spectroscopy results.

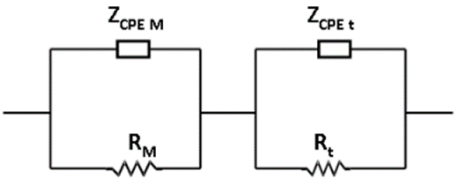

Table 1 - Evolution in time of electrochemical parameters of interest.

	15 d			60 d			240 d		
	R	**S**	**R-S24h**	**R**	**S**	**R-S24h**	**R**	**S**	**R-S24h**
OCP	-488	-550	-152	-658	-600	-450	-702	-715	-650
mV	±44	±43	±29	±42	±35	±23	±11	±15	±10
R_{p*}	84	53	3491±	21	24	153	10	13	55
kΩ cm^2	±34	±43	160	±3	±3	±35	±2	±2	±6
Q_M $\mu\Omega^{-1}$ cm^{-2} S^n	0.45	1.05	13.64	1.27	0.04	0.85	3.38	0.93	70.08
n_M	0.50	0.48	0.25	0.40	0.70	0.47	0.39	0.49	0.18
R_M Ω cm^2	1188	722	1333	1340	1306	1304	1146	1231	1366
Q_t $\mu\Omega^{-1}$ cm^{-2} S^n	113.5	116	36.91	125	148	118.9	162.5	189.5	152.9
n_t	0.72	0.75	0.90	0.69	0.65	0.79	0.76	0.72	0.78
R_t kΩ cm^2	33.60	34.39	2001.0	24.13	17.81	133.1	7.05	7.29	46.8
Chi square	0.008	0.001	0.001	0.009	0.009	0.005	0.009	0.007	0.010

Compressive strength was evaluated, and the average results were σR = (15.81 ± 0.84) MPa, σS = (10.50 ± 0.48) MPa and σR-S24h= (15.99 ± 1.20) MPa. A substantial decrease in compressive strength can be observed in the mortars that incorporate silicate ions (S). Porosity was calculated for not less than three samples. Mix R and R-S24h presents (19.10 ± 0.08) % and (18.54 ± 0.01) % empty space respectively, while mix S has (20.84 ± 0.11) %. In addition, lixiviation test indicates that silicates in mix S are producing a drop in the pH.

4 Conclusions

In contrast with previous results is simulating pore solutions, silicate ions do not contribute to mitigate steel corrosion when tested in mortar over 240 days. The differences with the blank samples tend to flatten after 60 days of exposure, presenting Rt values lower than 50 kΩ cm^2. The mechanical and physical properties of mortars that contain silicate ions can help to understand the electrochemical behavior. Evaluated on fresh specimens (7 days of curing), compression strength decreases, together with a decrease in the pH after lixiviation test. Also, the porosity increases when silicate ions are incorporated into the mixing water. However, mortars R-S24h presented Rt and Rp* values higher 50 kΩcm^2 after 240 days of exposure without affecting compressive resistance, pH or porosity.

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