STEEL CORROSION IN MORTAR SPECIMENS
DETERIORATED BY CHLORIDE INGRESS:
ELECTROCHEMICAL STUDY USING AC AND DC
METHODS AND MICROSCOPIC ANALYSIS OF
THE STEEL/MORTAR INTERFACE

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The electrochemical behavior of reinforcing steel in mortar specimens was investigated using two electrochemical methods: AC method Electrochemical Impedance Spectroscopy (EIS) and DC method Linear Sweep Voltammetry (LSV). Both methods aimed at monitoring the polarization resistance (R_p) of the steel surface, i.e., the resistance to current flow across the steel-mortar interface at the corrosion potential. The electrochemical phenomena were additionally studied and supported by visualization techniques and microstructure investigation using thin sections, electron microscopy and x-ray spectral analysis. Reinforced mortar specimens, 40 mm in diameter and 150 mm long were cast, using OPC CEM I 32.5, cement-to-sand ratio of 1:3 and water-to-cement ratio of 0.6. Each specimen contained a centrally located construction steel bar (6 mm in diameter) with exposed length of 80 mm. All specimens were cured in fog room conditions (95%RH, 20°C) for 14 days and placed in certain lab environment afterwards. A cylindrical titanium mesh served as counter electrode and SCE as reference electrode for the electrochemical measurements.

The EIS provided insight into the electrical properties of both the steel surface and the mortar. The electrochemical impedance Nyquist diagrams were plotted for the embedded steel in specimens under different conditions. Frequency range was 50.5 kHz to 10 mHz. The electrical properties of the steel/mortar interface and the corrosion process was characterized in terms of equivalent circuit, consisting of combination of resistances and capacitors (Fig.1). The resistance R_3 or R_4 , corresponding to the low frequency arc was adopted to estimate the polarization resistance of the steel bar. R_p in LSV approach was determined by scanning through a potential range of ± 20 mV close to the corrosion potential, using step potential of 1.22 mV and scan rate of 0.2 mV/s. The resulting current is plotted vs. potential and the corrosion current is related to the slope of the obtained plot. A comparison of R_p values derived from both methods are given in Fig. 2a. The corresponding changes in corrosion potential are shown in Fig. 2b. The formation of corrosion products and the lack of such in the reference samples are clearly revealed in Fig.3. Elemental mapping (Fig.4) was employed for evaluating changes in chemical composition of the mortar/steel interface. Structural information of the interfacial zone and the bulk mortar can be derived from BSE images (Fig. 5) by means of quantitative image analysis, allowing the assessment of microstructural changes due to the corrosion. Table 1 represents values for corrosion current, corrosion rate for the three specimens (4 and 5 are corroding samples and R as reference) at 65 and 120 days of cement hydration. The corrosion process in reinforced mortar can be successfully assessed by both AC and DC electrochemical methods. Combination of these methods with microscopic analysis of the mortar microstructure leads to better understanding of the involved electrochemical processes and the possibility for predicting the evolution of ion transport and durability properties of the materials.

Fig 1: Nyquist plots for sample 4 (left) and sample R (right)

Fig 2: a) R_p vs time and b) E_{corr} vs time

Fig 3: Thin sections of sample 4 (left) and sample R (right)

Fig 4: Elemental mapping (sample 4)

Fig 5: BSE images - sample 4 (left) and sample R (right)

time	sample	-E mV vs SCE	I _{corr} , A/cm2	Corr.rate mm/year
65	4	528	8.13E-08	5.61E-04
	5	522	2.78E-08	1.92E-04
	R	344	1.27E-09	8.74E-06
120	4	678	5.08E-07	3.50E-03
	5	814	1.58E-07	1.09E-03
	R	450	9.08E-09	6.27E-05

Table 1 E_{corr} , I_{corr} and Corr. rate of samples 4,5 and R for 65 and 120 days of cement hydration