Study of Lime Addition on Corrosion Resistance of Reinforced Mortar Of Carbon Steel and Galvanized Steel

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Introduction

In recent years it has grown the number of buildings whose reinforced concrete structures have shown pathological manifestations, mainly related to reinforcement corrosion [1]. The reinforcement corrosion in concrete has been recognized as a serious problem worldwide. In addition to the economic losses, public safety is also affected due to the loss of life associated with the collapse of bridges and concrete structures [2].
The use of reinforced concrete structures is based on the principle that the concrete is an ideal environment for steel, since it exhibits high alkalinity. The highly alkaline environment of Portland cement is responsible for the passivity of iron in pH from 12.6 to 13.5 (2). In accordance with the literature [3-7], such passivity is generally described as forming a protective layer composed mainly of oxide on the steel reinforcement, which provides adequate corrosion resistance. However, when concrete is continuously exposed to an aggressive environment, this passivation layer can be broken [1].

One possibility that has arisen with the use of mixed mortar is related to the effect of lime addition on the corrosion resistance of the reinforcement. Thus, this study aims to investigate the effect of adding lime mortar, seeking thus greater resistance to corrosion of reinforcing carbon and galvanized steel associated with an economic feasibility. The technique of electrochemical impedance spectroscopy was used to measure the value of polarization resistance of steel samples.

Experimental

The specimens were prepared in PRECON company and its composition is presented in Table 1.

Table 1 – Composition of samples

Mortar	**Trace (% mass, cement, lime, sand)**	**Lime concentration (% mass)**
High content of lime	1:2.5:6	26.3
Medium content of lime	1:1:6	13.3
Minimum content of lime	1:0.5:6	6.7
Without lime	1:0:6	0

The wires of carbon steel or galvanized steel with a diameter of 5.00 mm were used. The identification of molds according to the mixture and the type of frame was made considering the lime content: E (high), M (medium), B (low), S (no lime) and the type of armor: G (galvanized), A (carbon steel).

The open circuit potential was measured on samples as received. The equipment used was the Omnimetra PG-29, the reference electrode was Ag/AgCl, and the counter electrode was an austenitic stainless steel plate. The Electrochemical Impedance Spectroscopy (EIS) was performed using a AUTOLAB 30 potentiostat, and the data acquired by the FRA for Windows v. 2.3 of Eco Chemie B. V. The frequency range used was from 100 kHz to 1 mHz, with an amplitude of 20 mV AC. These measurements were repeated after 36 months of NaCl immersion testing to determine the effect of time on the armor. Measurements of open circuit potential and electrochemical impedance spectroscopy were repeated using the potentiostat Princeton Versastat 3. Data were acquired by software VersaStudio. The impedance results were treated using the software ZsimpWin.

Results and Discussion

The obtained values of corrosion potential were shown in Table 2.

Table 2 – Results of Ecorr of reinforced mortars

Samples	Ecorr $(mV)_{Ag/AgCl}$ Galvanized steel	Ecorr $(mV)_{Ag/AgCl}$ Carbon steel	Ecorr $(mV)_{Ag/AgCl}$ Galvanized steel (after 36 months)	Ecorr $(mV)_{Ag/AgCl}$ Carbon steel (after 36 months)
Without lime	-880	-550	-378.5	-450.9
Low lime content	-695	-540	-416.5	-486.7
Medium lime content	-740	-450	-458.9	-472.8
High lime content	-720	-425	-447.8	-464.4

In the beginning of project, there is an increase in corrosion potential of steel with increasing concentration of lime in the mortar. This result demonstrates the beneficial effect of lime on corrosion resistance of steel. In the case of lime addition on mortar, carbon dioxide gas is necessary for curing the mortar with calcium oxide in masonry. The CO_2 improves the passivation of zinc region and contributes to increase the corrosion resistance of galvanized steel.

After 36 months, the corrosion potential becomes higher, except for the specimens of medium-high content of lime for the carbon steel armor. This result can be due to the increase of alkaline content in mortar.

The results of electrochemical impedance spectroscopy are shown in Table 3 and 4.

Table 3 – Polarization resistance of carbon and galvanized steels in mortars with and without lime addition

	Carbon steel			Galvanized steel	
Sample	$Re(\Omega.cm^2)$	$Rp(\Omega.cm^2)$	Sample	$Re(\Omega.cm^2)$	$Rp(\Omega.cm^2)$
SA	32.1	6.5	SG	1.8	29.9
BA	15.7	14.9	BG	17.0	24.5
MA	5.6	13.1	MG	6.8	56.8
EA	8.0	17.8	EG	1.3	68.1

Table 4 – Polarization resistance of carbon and galvanized steels in mortars with and without lime addition after 36 months

	Carbon steel			Galvanized steel	
Sample	Re(Ω.cm^2)	Rp(Ω.cm^2)	Sample	Re(Ω.cm^2)	Rp(Ω.cm^2)
SA	30.4	46.6	SG	7.1	36.6
BA	31.3	53.8	BG	16.2	49.1
MA	30.9	38.2	MG	16.1	37.5
EA	6.1	12.1	EG	10.0	16.2

The lowest resistance of electrolyte was observed in mortars with the highest lime content, except for the galvanized steel in mortar after 36 months.

In the beginning of project, the polarization resistance increased with increasing of lime content in mortar, demonstrating the protective effect of lime. This result was observed for carbon and galvanized steel. After 36 months, the polarization resistance of steel in mortars with high content of lime was the lowest. In the beginning of project, the best corrosion behavior was observed for carbon and galvanized steel in high content of lime in mortars. After 36 months of molding, the highest corrosion resistance of steel was obtained for the addition of low and medium concentrations of lime in mortars. The steels in mortar with high content of lime showed the lowest corrosion resistance after 36 months of life.

For the carbon steel in mortar, the polarization resistance increased with time for the mortar without lime and with low and medium contents of lime. The corrosion potential of carbon steel increased with time for the mortar without lime and with low content of lime.

For the galvanized steel in mortar, the polarization resistance increased with time for the mortar without lime and with low content of lime. The corrosion potential of galvanized steel in mortar increased with time for all samples.

Conclusions

In the beginning of project, the polarization resistance increased with increasing of lime content in mortar, demonstrating the protective effect of lime. This result was observed for carbon and galvanized steel. After 36 months, the polarization resistance of steel in mortars with high content of lime was the lowest.

For the carbon steel in mortar, the polarization resistance increased with time for the mortar without lime and with low and medium contents of lime. For the galvanized steel in mortar, the polarization resistance increased with time for the mortar without lime and with low content of lime.

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