Int. J. Electrochem. Sci., 12 **(2017)** 22 – 31, doi: 10.20964/2017.01.08

International Journal of ELECTROCHEMICAL SCIENCE
www.electrochemsci.org

Short Communication

Corrosion Study in Reinforced Concrete Made with Mine Waste as Mineral Additive

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Received: 23 September 2016 / *Accepted:* 7 November 2016 / *Published:* 12 December 2016

This work studies an alternative to reuse mine waste materials in reinforced concrete. It pretends to determinate experimental parameters of corrosion resistance in different systems of concrete assesed, (with 5%, 10% y 15% recycled material instead of cement Portland) in comparison to conventional reinforced concrete. Specimens of concrete were exposed in a corrosive environment using a salt spray chamber. At the moment of assesing of the steel-concrete system in relation to exhibition time were used techniques half-cell potential and electrochemical impedance. It is worth mentioning that the half-cell potential indicates specimens with mine waste material does not suffer a significante change in comparison to conventional concrete system in relation a monitoring time. The results obtained by Electrochemical Impedance Spectroscopy technique show systems with mine waste material presents a slight diminish in the values of corrosion resistance and the total impedances does not show a significant change between to conventional concrete and a specimen with 10% of mine waste material.

Keywords: Corrosion, concrete, mine waste, electrochemical impedance, half-cell potential.

1. INTRODUCTION

Nowadays, mine waste materials in the city has no use, due neglect and careless it has become part of natural landscape. Nevertheless, its chemical and physical characteristics are not favorable for environment and healthy of people. The particles are so fine that permeate the air producing large eddies of land. Moreover, needs of infrastructure and equipment of a city in constant development requires more spaces to build it. Right now, that spaces are occupied by dams of mine waste [1-3].

Considering the previous, it is necessary to use this abundant resource and at the same time, mitigate its negative impact on environment with introduction of new alternatives [4]. Implementation of mine waste in construction industry, specifically in reinforced concrete for structural elements of low resistance would be an efficient solution encouraging higher advantages for society.

Construction industry in Mexico and all the world has been supported along many generations by using of reinforced concrete as fundamental element of structures. Construction costs are relatively low and its characteristics has guaranteed the useful life of buildings [5]. Nevertheless, maintenance of structures has been neglected, thus, corrosion effect in structures has become in one of the most harmful factors for useful life of buildings. This phenomena can seriously damage the functional properties of concrete such as adhesion and mechanical strength, as well as favors the formation of cracks and landslides chunks of concrete compromising the structural integrity [6]. Therefore, the analisys of corrosion effects in structures are so important because this phenomena generate millions in losses around the world. A variety of methods have been applied to prevent the corrosion of reinforced steel in agressive enviroments such as inhibitors, galvanization, epoxy coating, re-alkalization of carbonated concrete, cathodic protection, and electrochemical chloride extraction. [7-10]. It has been observed that durability of structures and its service life diminishes in presence of chloride ions in reinforced concrete do to it favors the reinforcement corrosion process [11,12].

This work seeks to obtain benefits by reusing of mine waste materials in different percentages as sustitute of cementitious in reinfored concrete systems. There are many studies published about chloride ions penetration related with concrete composition [13,14]. It would be considerated only for structures with lower resistande to guarantee functionality faced with this phenomenon in comparison with conventional reinforced concrete. Confirming the benefits in construction industry [15,16].

2. EXPERIMENTAL

2.1. Corrosive environment

Figure 1. Salt spray chamber

The systems of reinforced concrete were exposed in a synthetic corrosive environment (5% NaCl) [17] using a salt spray chamber by 30 days (Figure 1) [18].

2.2. Waste material used

In this work it was used mine waste material from Escombrera Presa Sur, located in Pachuca-Real del Monte District, Hidalgo, Mexico (Figure 2). The study of characterization indicates as major compounds silice oxide, aluminum oxide, and iron oxide (Table 1) and mineral species obtained by diffractograms by X-Ray Diffraction (Figure 3).

For the characterization it was made a composite considering the similarity sample from the analized area. The methods applied were: X-ray diffraction using a Philips diffractometer, model X'Pert. It was necessary prepare the sample -200+270 mesh (74-53 μm) for this analisys. Quantification of elements inside the material in study from each Escombrera, was made by atomic absorption spectrophotometry technique with a Perkin Elmer equipment Model 2100. The study of morphology and compactness of the particles from the escombreras was made by using the scanning electron microscopy with energy dispersive microanalysis X-ray (SEM-EDS). Finally, it was obtained the microanalysis study to determinate the nature of the material studied using the equipment SEM, Jeol brand, model JSM 6300 equipped with EDS.

Figure 2. Mine waste material.

Table 1. Chemical composition from Escombrera Presa Sur

Element	%	Element	%
SiO_2	70.01	P_2O_5	0.08
TiO_2	0.30	K_2O	3.98
Al_2O_3	12.82	CaO	3.34
Fe_2O_3	3.80	Na_2O	2.50
MnO	0.70	Ag	38 g Ag /Ton
MgO	1.01	Au	0.25 g Au / Ton

Figure 4 shows an overview of tailings, which were analized by SEM – EDS. It can be observed higher percentages of silice, aluminum, potassium and iron, at the same time, minor percentages of elements as sulfur, magnesium, manganese and trace elements such as copper, zinc.

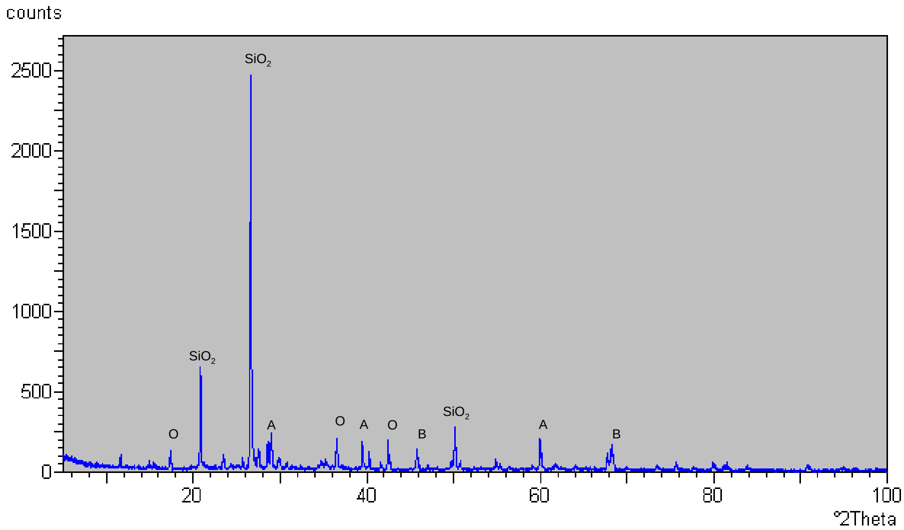
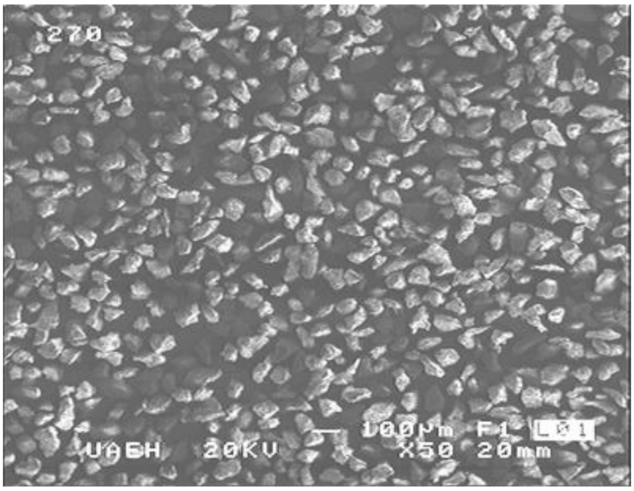
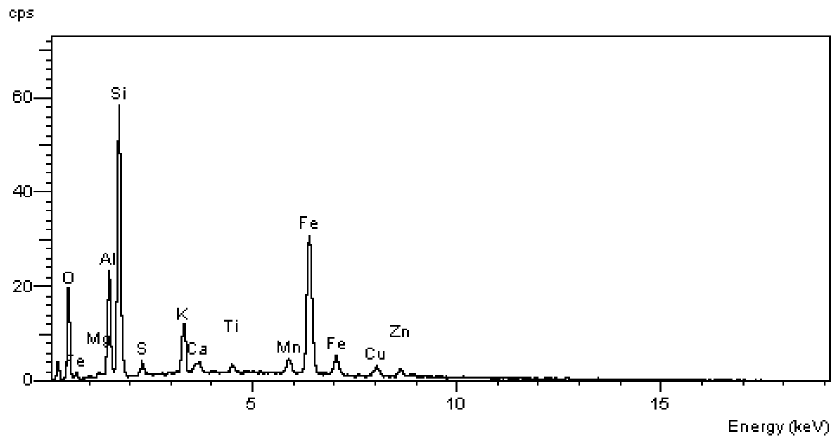


Figure 3. X-ray diffraction pattern - Escombrera Presa Sur.



a)



b)

Figure 4. Tailing Microfotographs a) Overview, 50X, SEM, b) microanalysis overall results SEM-EDS.

2.3. Preparing Specimens

During the concrete mixing is added in relatively large quantities of mineral admixtures, finely divided siliceous materials. The primary source of mineral admixtures are industrial by-products. Researchers call mineral admixtures as supplementary cementing materials (SCM), however, in Europe call them additions. The compounds of traditional concrete are: cement, water, fine aggregates and coarse aggregates. On the other hand, a contemporary concrete contains 2 extra components: chemical admixture and SCM (called for some researchers the 6th component of concrete). Mineral admixtures commonly used are silica fume, slag, fly ash and metakaoline. In this work, mine waste material is used as a mineral admixture (silica fume) due both has similar composition . The portland cement can be replaced from 5 to 15% by silica fume. Silica fume favors concrete properties in pozzolanic reaction and particle packing. Inasmuch as the magnitude of silica fume is two sizes of order smaller than that cumulative mass, % finer of Portland cement, it can easily fill in the space between cement particles [5].

There were made rectangular specimens of concrete 15*15*15 cm length (Figure 5). The mine waste material was used as cementant with a dosage of 5%, 10% y 15% replacing ordinary cement Portland (table 2) designed for f'c 150 kg/cm^2.

Table 2. Concrete dosage

Concrete batching with 5% of mine waste material					
Water kg/m^3	Cement kg/m^3	Coarse Aggregate kg/m^3	Fine Aggregate kg/m^3	Mine waste kg/m^3	Water-Cement ratio
214.9	309.2	1148.7	439.9	21.5	0.61
Concrete batching with 10% of mine waste material					
Water kg/m^3	Cement kg/m^3	Coarse Aggregate kg/m^3	Fine Aggregate kg/m^3	Mine waste kg/m^3	Water-Cement ratio
214.88	284.3	1148.7	437.2	41.6	0.61
Concrete batching with 15% of mine waste material					
Water kg/m^3	Cement kg/m^3	Coarse Aggregate kg/m^3	Fine Aggregate kg/m^3	Mine waste kg/m^3	Water-Cement ratio
214.88	260.3	1148.7	437.2	60.53	0.61

2.4. Specimen preparation

Figure 5 shows dimension of test specimens. The test specimens were fabricated in cubic molds with 150*150*150 mm length. That dimension was designed considering the appropriate size and shape to obtain the corrosion potential and current corrosion measurement. After removal from the mold, the specimen were water-cured in an accelerated curing chamber for 24 hours at temperature of 65 ± 5 °C.

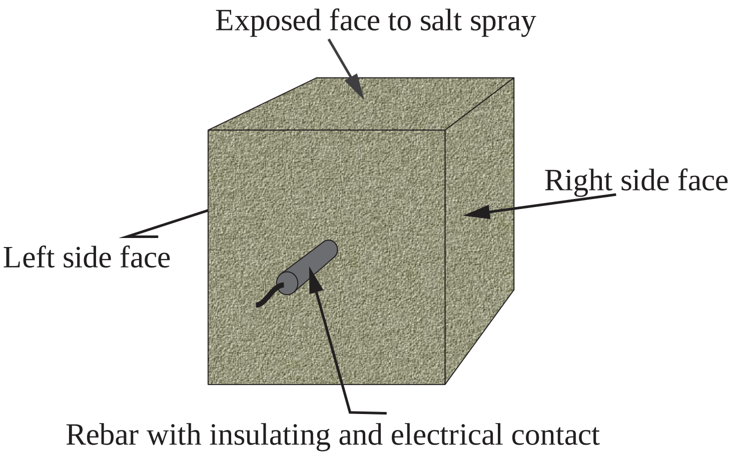


Figure 5. Test specimens.

2.5. Experimental Setup

When it was applied the half-cell potential method, the concrete surface was maintained in a condition of wetness for 30 min prior to the measurement. It was made an experimental arrangement for electrochemical techniques, in which there were used three-electrode cell setup with a standar electrodo, (i.e., saturated copper sulfate electrode) as reference electrode and a graphite bar as counter electrode. As working electrodes, rebar of low AISI 1018 carbon steel (C 0.15/0.20%; Mn 0.60/0.90%; Si 0.15/0.30%; P max. 0.04%; S max. 0.05%), (figure 6). The measurements of the electrochemical impedance spectroscopy technique (EIS) were carried out with an amplitude of 10 mV (vs. o.c.p.) and in the frequency range of 10 mHz to 10 kHz. It was used a Potentiostat-Galvanostat Autolab Mod PGSTAT30 with Frequency Response Analyzer (FRA) and it was managed with software of the same company.

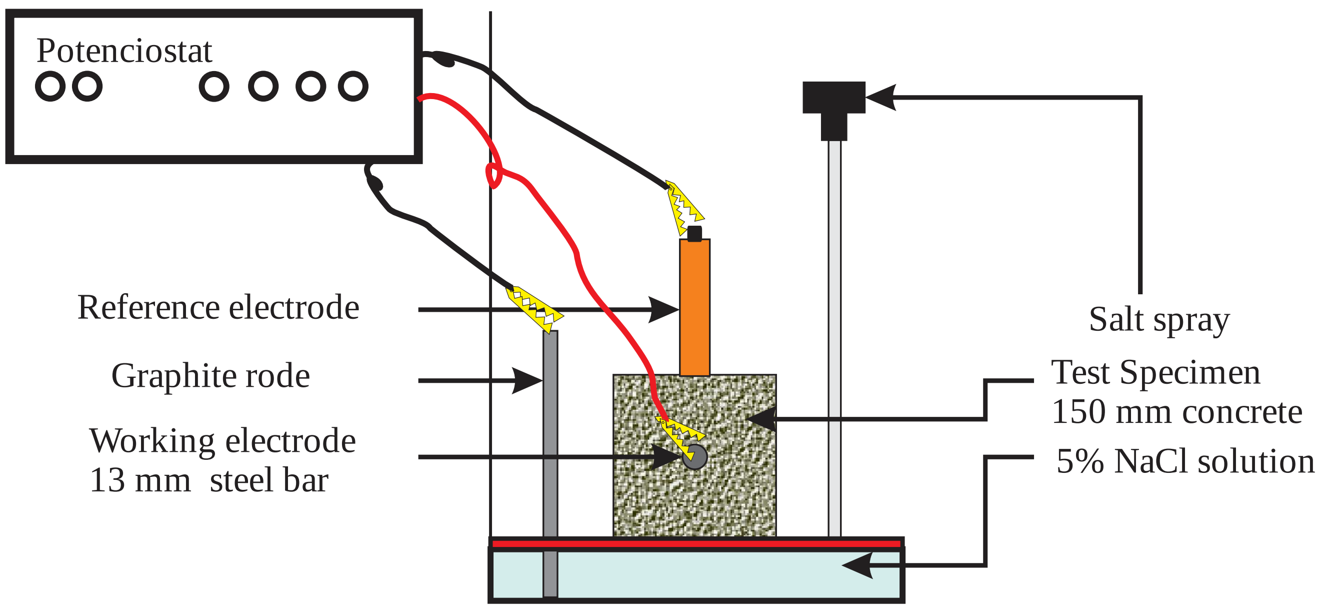


Figure 6. Experimental arrangement

3. RESULTS AND DISCUSSION

3.1. Half-cell potentials

Figure 7 indicates the results of half-cell potentials for the systems assessed whit different dosages of mine waste material as cementitious in relation of exposure time (28 days) inside a salt spray chamber [17-19]. It is worth mentioning, that the results corresponding to exposed surface of specimen shows a similar behavior with specimens with 0% dosage of mine waste material. After 10 days inside a salt spray chamber it can be seen the potentials presents a linear behavior without a significant change in potential values. Otherwise, the potential values in right and left surface show a similar behavior in comparison to some studied systems with the surface exposed to aspersion. It presents the same linearity at 10 days observing a slight increasing in potential values in comparison to conventional system. Such fact indicates the corrosion resistance is very similar between a conventional concrete to a dosages analyzed.

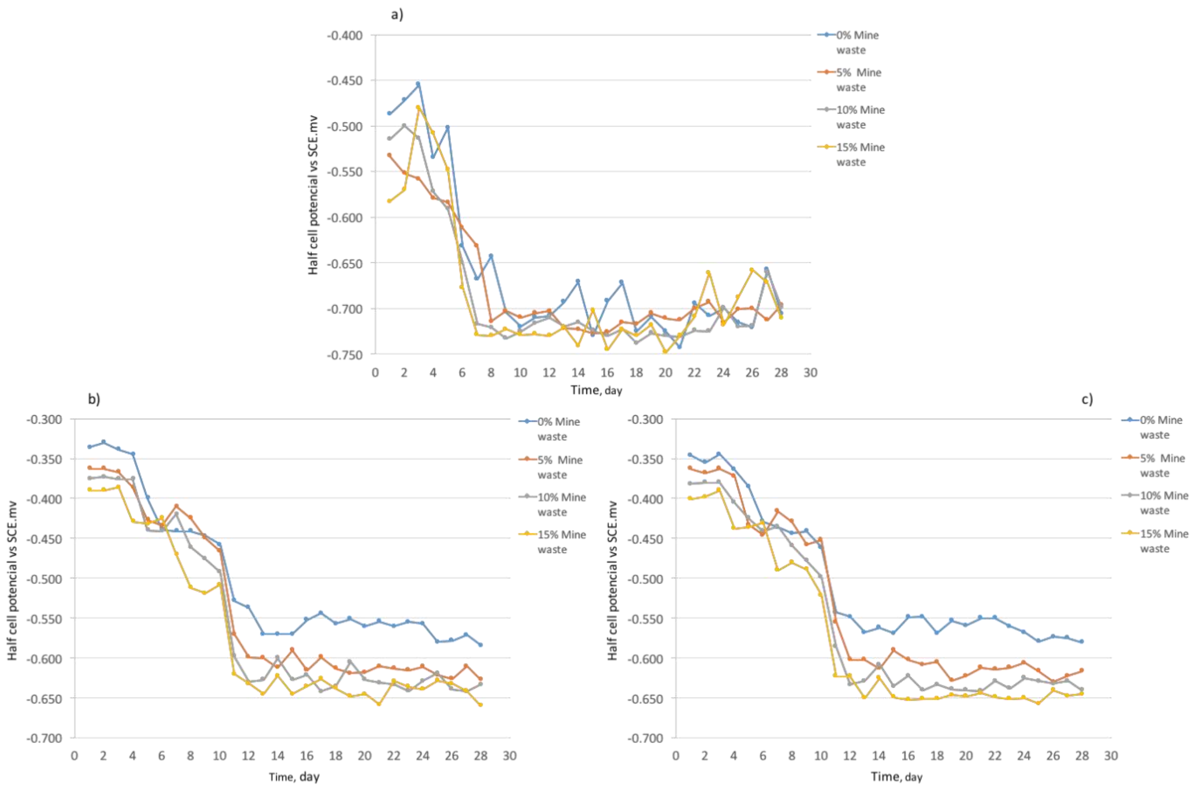


Figure 7. Half-cell potentials a) surface directly exposed b) right surface y c) left surface

In order to determine more precisely the corrosion effect in systems with presence of mine waste material which has been assessed, the measurements were performed with the technique of Electrochemical Impedance Spectroscopy.

3.2. Corrosion parameters obtained of electrochemical impedance spectroscopy technique.

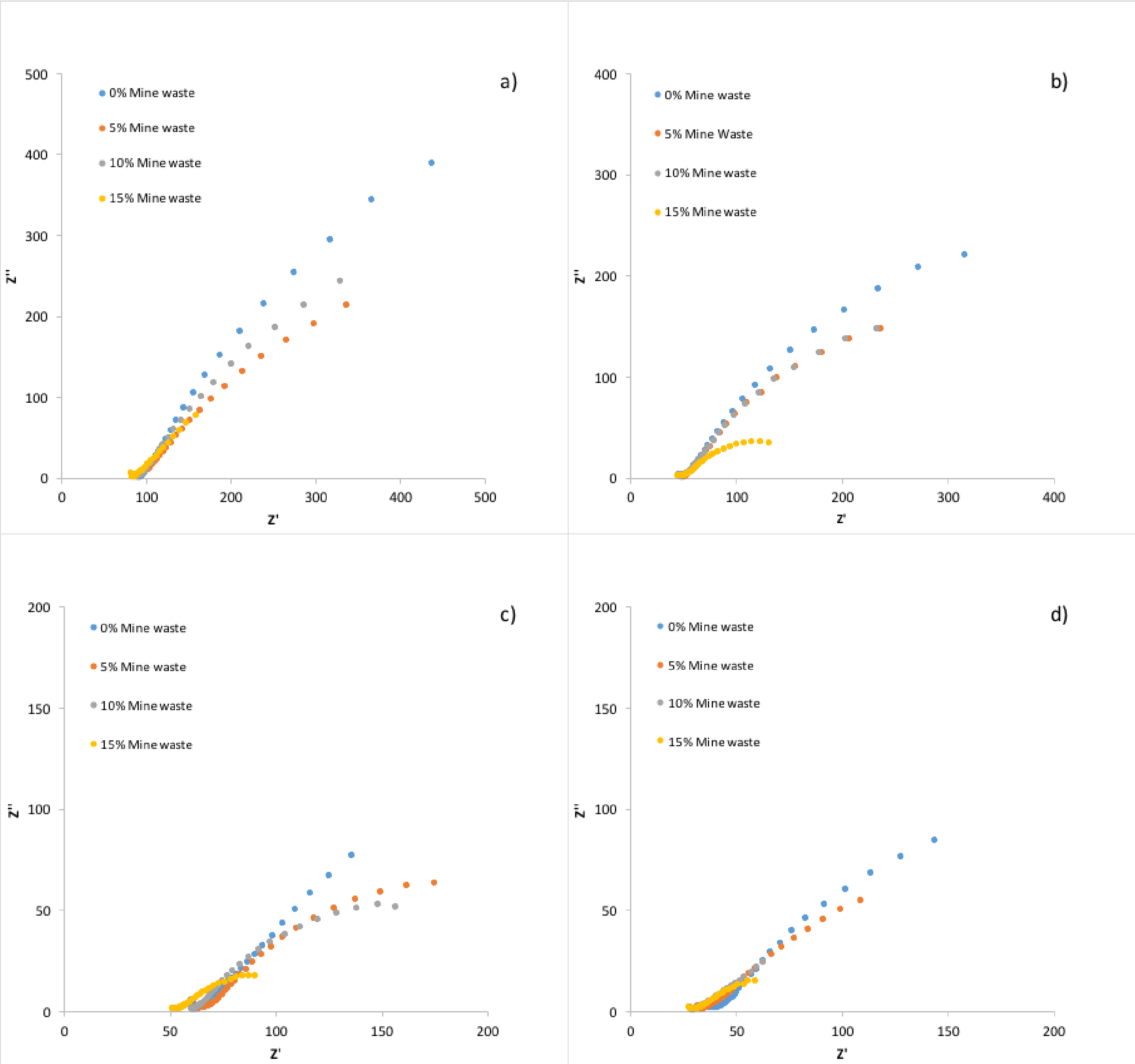


Figure 8. Nyquist diagrams for Steel-concrete systems with mine waste as cement (5%, 10% y 15%) (a) 7 days b) 14 days c) 21 days and d) 28 days.

Figure 8 presents the Nyquist diagrams from the measurements of electrochemical impedance spectroscopy technique for the systems assessed in relation to exposition time inside a corrosive environment (28 days). They display in general, open semicircles with a slight lineal tendency at low frequencies. Such fact can be attributed primarily to the charge transfer and after the dissemination of either corrosion products into the solution or corrosive species into the surface [20, 21]. It can be seen a decrease in the real and imaginary values of impedance by increasing mine waste percentage as cementitious up to 15%. In regards of systems with 5% y 10% of mine waste the values do not observe a significant change in comparison to conventional concrete (0% mine waste material). It is worth to mentioning the systems with presence of mine waste as cementitious up to 10% show a similar behavior at high and low frequencies. On the other hand, systems with 15% of mine waste do not show this behavior, instead of, diminish the resistance to the corrosion process, in comparison to systems with low concentrations.

Table 3 shows corrosion parameters of systems with different dosages of mine waste as cement. It can be seen the Ecorr values are very similar for studied systems. This indicates that the energy conditions at the beginning are almost the same. Otherwise, it shows the polarization resistance value (Rp) diminish when increasing the percentage of mine waste as cement in relation to exposition time for every system. For 15% dosage, this decrease is higher. It is worth mentioning that the polarization resistances diminish as increasing the time for all systems assessed. Therefore, the corrosion rate is very similar up to 10% dosage of mine waste in comparison to conventional system.

Table 3. Corrosion parameters obtained from the electrochemical impedance spectroscopy technique.

Time	% mine waste	E_{corr} /(mV)	Rs/Ω	Rp/Ω
7 days	0	-0.732	92	950
	5	-0.712	87	710
	10	-0.730	90	660
	15	-0.735	86	215
14 days	0	-0.702	46	692
	5	-0.725	48	412
	10	-0.724	49	398
	15	-0.728	47	153
21 days	0	-0.722	62	311
	5	-0.738	65	214
	10	-0.734	62	185
	15	-0.744	55	87
28 days	0	-0.699	38	289
	5	-0.706	34	176
	10	-0.715	30	132
	15	-0.720	29	69

4. CONCLUSIONS

The results of half-cell potentials do not show a significant change in comparison to a conventional concrete up to 10% dosage mine waste.

The technique of electrochemical impedance spectroscopy indicates interaction of mine waste as cementitious in concrete mix does not modify the corrosion process. It can be seen that the addition of mine waste up to 10% does not encourage the arrival of corrosion agents into the surface of steel rebar in comparison to a conventional system.

The values of Rp are very similar for all systems. Chlorides interaction with metal,it is increased by using 15% dosage of mine waste as cementitious modifying considerably the corrosion rate of system.

ACKNOWLEDGEMENTS
Authors thank to PRODEP, to UAEH and BUAP by the financial support to the project.

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