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Effect of Air Entraining Admixture on Corrosion of Reinforced Concrete

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Abstract

Reinforced concrete structures affected by the attack, sulfates, carbonates and chlorides. The most important factor in the corrosion of reinforced concrete structures is due to chloride attack and prevent corrosion of the reinforcing steel is done by reducing chlorides through the concrete appropriate thickness of reinforced concrete which also controls the permeability of concrete coating layer occurs. So in this study, 5 mix with various of air entraining admixture on cylindrical sample along with 15 mm reinforced bar has been defined for preparation test samples which is aimed to determine corrosion and water absorption properties. Results shows that air entraining have a huge impact on water absorption and electrical resistivity of concrete.

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Keywords: Reinforced Concrete; Corrosion; Air Entertainment; LPR test.

1. Introduction

Chloride-induced corrosion is the main factor in determining the durability and service life of the

Reinforced concrete structures exposed to marine environments (Prediction of Long-Term Chloride Diffusion in Silica Fume Concrete in a Marine Environment).

One effective method for preventing corrosion of steel reinforcement and improving the mechanical

Properties of concrete is changing the physical nature of concrete by adding different materials (Kakooei, Akil et al. 2012).

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Concrete compounds play a significant role in the corrosion of concrete and rebar. That the main causes of corrosion are the chlorides in reinforced concrete. One of the components is air entraining admixture (AEA) that will be used as admixture for concrete. The fine air-bubble system in a cement paste or a concrete mix improves its performance for the freeze-thaw environment. A lot of researches has been applied to study of AEA effect on mortar and concrete; such as effect of AEA on cracking and severity of cracking Gecko, A., Nagasaki, S., Saeki, T., & Hisada, M. (2004), micro pore size distribution (Ouyang, Guo et al. 2008). estimation of the air void by a high quality flatbed scanner, scanning electron microscopy at low and high temperature, morphology of hydrating particles and workability, mechanical, acoustic, and thermal properties (Corr, Juenger et al. 2004, Zalocha and Kasperkiewicz 2005).

It is also measured dynamic adsorption and equilibration of AEA onto the cement and ash surfaces. This discussion is about the relative importance of unburned carbon versus free Ca2+ and Mg2+ surface sites on AEA uptake is ash dependent and not exclusive to either carbon or free ions independent of each other(Stencel, Song et al. 2009). The early composition of the air void shell is very similar to the bulk cement paste but with a lower C3S content, higher amounts of other anhydrous phases, and higher CaCO3 content(Ley, Chancey et al. 2009). It is studied that every 1% increase in air content increases the transport coefficient by about 10% or decreases it by 4%, depending on whether the air voids act as conductors or insulators (Wong, Pappas et al. 2011).

The type of AEA is very important admixture in concrete. Because of the air content in concrete due to synthetic surfactants, AEA produces the smallest and most closely spaced air voids, followed by saponified acid resin AEA (Łaźniewska-Piekarczyk 2013).

The AEA has a dual nature; one portion of the molecule is polar, and the other portion is nonpolar that are sometimes termed the polar head and the nonpolar tail. The polar portion of the molecule can be one of three types. If it is negatively charged, the substance is an anionic surfactant. Examples are carboxylates (COO-) formed from the neutralization of carboxylic acids, sulfates (SO, O-) from sulfonic acids, and sulfate esters (SO, O-). If the head is positively charged, the surfactant is cationic. The most common example is substituted ammonium ion (NH+). If the polar portion is uncharged, the material is a nonionic surfactant. The most common examples of soluble nonionic surfactants are polyoxyethylenated compounds in which the polarity and solubility are derived from a (CH, CH, O), structure, with x being about 15 for products used in concrete. The nonpolar tail of the molecule is frequently a straight or branched chain hydrocarbon group of perhaps eight to twenty carbon atoms, alkyl (S-15 carbons) benzene groups, or larger polymeric structures. This portion must be comparatively large for there to be significant surface activity; a short chain will not do (Ramachandran 1996).

There are a lot of researches has been done on effect of concrete components to corrosion of rebar. Of course there is few researchers have associated the amount of air and examined how it effects and optimizes corrosion (Ahmad 2003, Dotto, De Abreu et al. 2004).

In corrosion investigation, aggressive ion concentration is very important. Chloride ion (Cl-) is the aggressive anion that has more effects on corrosion properties. Because Cl- has the small radius than other aggressive ions, so its diffusion ability is high. Also Cl- is presented in many of our environments (Glass and Buenfeld 1997, Gleiter 2000).The linear polarization resistance (LPR) test is the useful method to investigate the corrosion potential, current density and polarization resistance. These characterizations are obtained by Toefl extrapolation method from LPR test (Gleiter 2000), Gowers, K. R., & Millard, S. G. (1993).

The present study was undertaken to verify the how material adhesives change the rate of concrete rebar corrosion. The AEA effects on concrete corrosion were investigated by LPR test and Toefl extrapolation.

2. Experimental

2.1. Materials used

Portland cement typed II having the compressive strength of 52.5 MPa from Torbat Cement factory (Iran) by the chemical characteristics listed in Table 1 is used.

Table.1. Chemical compositions of cement

Materials contents	Sio_2	Al_2o_3	Fe_2o_3	Cao	MgO	K_2o	Na_2o	other
Percentage	21.29	5.03	4.03	63.29	2.81	0.54	0.42	0.95

The aggregate gradation is accordance of ASTM shown in Fig. 1, and the consumptions of steel St 37 16 mm diameter bars are used.

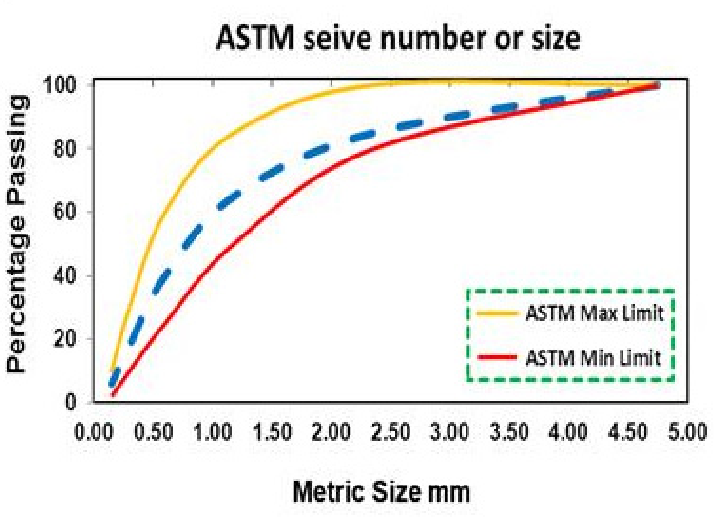


Fig. 1. Curve of grading of sand used in mortar

Total number of 5 samples is prepared with the various percentages of air entraining admixture in the cylindrical diameter 10 and height of 15 cm, which shown in Fig. 2.

Fig. 2. Producing and testing

And each of the samples after pouring concrete rebar with the diameter of 16 mm (Fig. 3) was placed in the center. All types of concrete after 28 days of curing put under solution containing 3.5% percentage Nacl for the corrosion tests. The composition of the concrete is given in Table 2.

Fig. 3. Rebar embedded in reinforced concrete

Table 2. Mix design

Number of Sample	1	2	3	4	5	6
Cement(gr)	700	700	700	700	700	700
Water(gr)	350	350	350	350	350	350
Fine Aggregate(gr)	2000	2000	2000	2000	2000	2000
Air Entraining Agent(ml)	25	20	15	10	5	0

2.2. The LPR test

The LPR test performed to investigate corrosion potential, current density and polarization resistance of concrete rebar. The LPR test was conducted by Auto lab (PGSTAT 12). The samples were tested after two weeks immersion in 3.5% NaCl solution. The electrochemical cell was collected with rebar as working electrode, platinum as counter electrode and saturated calomel as the reference electrode. Fig 4 is the schematic of used electrochemical cell in this investigation (Anandkumar, B., & Shi, W. (2009).

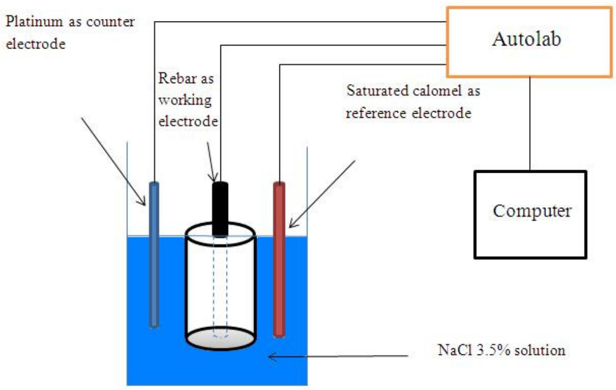


Fig. 4. Schematic of used electrochemical cell

3. Result and discussion

It can be seen in fig 5; potential charts versus current density were obtained by LPR test for every sample.

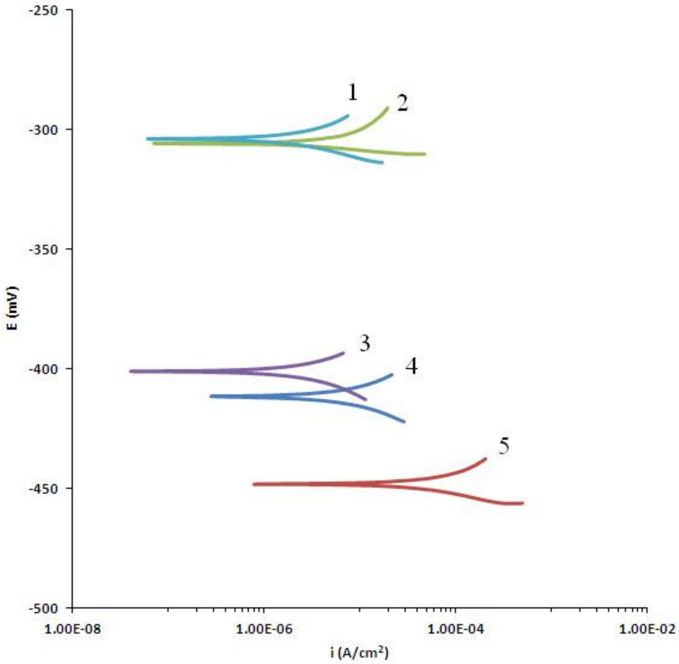


Fig. 5. The LPR result of samples

The corrosion potential, current density and polarization resistance data were acquired by Toefl extrapolation method on the chart.

- These data are given in figure 6. According to these figure, by air entraining agent content, increasing in concrete, corrosion potential and polarization resistance was decreased. Furthermore current density (corrosion rate) values increased. Polarization resistance was calculated from the Stern-Geary equation that follows:
- Where the Rp is the polarization resistance, icorr is corrosion current density and B is the proportionality constant. B was considered 26 for this test that calculated from this equation:

Ba and BC are Toefl anodic and cathodic slopes respectively that obtained from LPR chart.

As can be shown in fig 5, by air entraining agent content increasing, polarization resistance was decreased.

Air entraining agent addition causes the porosity in concrete. So air entraining agent raising result in higher porosities amounts. The concrete is dissolved slowly in 3.5% NaCl solution and Si_4^+ and Al_3^+ cations are released Andersen, P. J. (1986), Ataman, H. N., Carlos, C., Chae, S., Monteiro, P. J. M., & Bastacky, J. (2008). Released cations, hydrolysis in porosity according to these equations:

$$Si_4^+ + 2H_2O \rightarrow Si\,(OH)_4 + H_3O^+$$

$$Al_3^+ + 2H_2O \rightarrow Al\,(OH)_3 + H_3O^+$$

Then positive charge increases in porosity of concrete. So Cl- anion (negative charge) migrates to porosity to obtain electro neutrality.

$$Cl^- + H_3O+ \rightarrow HCl + H_2O$$

Thus dissolution rate increases because HCl is strong Lewis acid. So porosity environment becomes acidic locally.

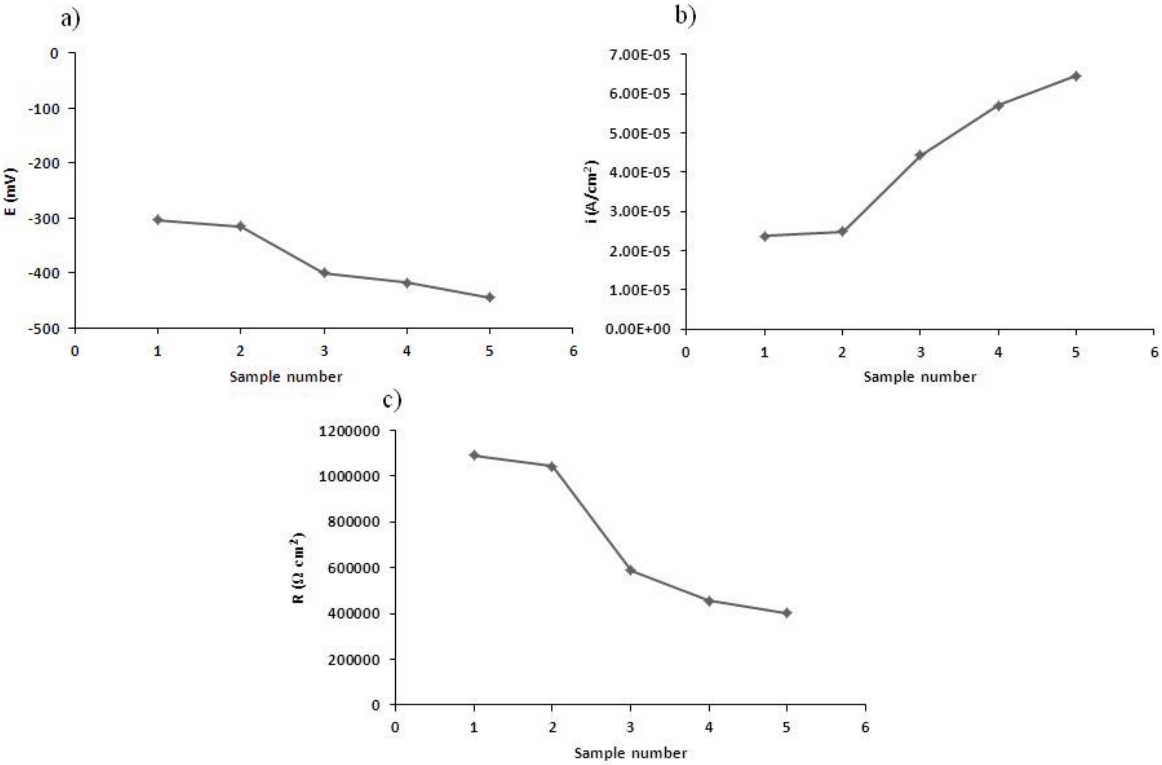
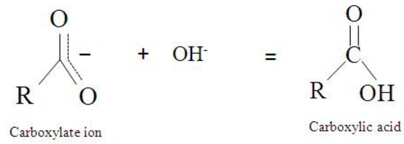


Fig. 6. Toefl extrapolation results for a) corrosion potential b) corrosion current density c) polarization resistance

In other hands, Air entraining agents have carboxylate base that hydrolysis by OH^-



By carboxylic acid formation, pH value was decreased and dissolution rate increases.

Therefor by air entraining agent increasing, concrete dissolution rate increases and rebar more corroded. Then corrosion potential and polarization resistance are decreased. Also corrosion current density increase.

4. Conclusions

The following conclusions can be drawn from this research:

1. Air entraining agent prevents contraction due to water freezing in concrete. So air entraining agent addition to concrete is useful.
2. However by air entraining agent increasing, corrosion properties. The corrosion potential and polarization decreased and corrosion current density increases.
3. The results show according to LPR results addition of 5 ml air, entraining agent to concrete is suitable; because corrosion properties decreasing are negligible in this condition.

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