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Corrosion resistance of SS316L in simulated concrete pore solution in presence of trisodium citrate

INTRODUCTION

Reinforced concrete is widely used for building materials and plays a significant role in economic development. However, the premature degradation of reinforced concrete structures due to the reinforcing steel corrosion has become a serious problem in modern society, which results in a huge economic loss [1, 2, 3].

Under normal conditions, reinforcing steel in concrete can be protected from corrosion by forming a compact passive film on its surface in concrete pore solution with high alkalinity (pH 12.5-13.5). However, the passive film can be locally damaged and the localized corrosion of reinforcing steel takes place when pH and/or the chloride concentration at the steel/concrete interface reach the critical values for corrosion [4-9]. The pH of concrete pore solution decreased during concrete carbonation due to the neutralization of $Ca(OH)_2$ in the interstitial solution with the acidic gases (CO_2, SO_2, etc.) which diffuse into the steel/concrete interface from the air [8]. The pH value of concrete pore solution is one of the most important parameters affecting the corrosion behaviour of reinforcing steel in concrete.

In spite of the extensive studies of corrosion behaviours of reinforcing steel [4, 6, 9, 10], the exact mechanism of its depassivation is still unclear. Even though the effect of pH on the corrosion of reinforcing steel was discovered decades ago, there were only a few studies focusing on the depassivation of the steel caused by decreasing pH of concrete pore solution during the carbonation process [8, 11, 12, 13]. In the urban and industrial areas, the acidic gases (CO_2, SO_2, NO_2, etc.) can make the local atmosphere acidic, and attack the hydrated concrete. The reactions of neutralization in concrete may decrease the pH value of concrete pore solution, induce the steel surface depassivation, and consequently cause the steel corrosion.

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Several research papers have investigated the corrosion behaviour of metals in presence of simulated concrete pore (SCP) solutions [14-25]. Usually steel rebars have been used in such studies. The present study is undertaken to investigate the corrosion behaviour of SS 316L, in simulated concrete pore (SCP) solution in presence of trisodium citrate (TSC). A saturated solution of calcium hydroxide is used as SCP solution [26-31]. Electrochemical studies such as polarization study and AC impedance spectra have been used to evaluate the corrosion resistance of the materials under investigation.

MATERIALS AND METHODS

Simulated Concrete Pore solution

A saturated solution of calcium hydroxide was used. The pH of the solution was 10.17.

Metal specimens

SS316L (Composition (wt %): 18 Cr, 12 Ni, 2.5Mo, < 0.03 C and balance iron [32]), wire of 1mm diameter was used in the present study.

Potentiodynamic polarization

Polarization studies were carried out in a CHI – Electrochemical workstation with impedance, Model 660A. A three-electrode cell assembly was used. The working electrode was one of the three metals. A saturated calomel electrode (SCE) was the reference electrode and platinum was the counter electrode. From the polarization study, corrosion parameters such as corrosion potential (E_{corr}), corrosion current (I_{corr}) and Tafel slopes (anodic = b_a and cathodic = b_c) were calculated.

AC impedance spectra

The instrument used for polarization study was used to record AC impedance spectra also. The cell setup was also the same. The real part (Z') and imaginary part (Z") of the cell impedance were measured in ohms at various frequencies. Values of the charge transfer resistance (R_t) and the double layer capacitance (C_{dl}) were calculated.

RESULTS AND DISUSSION

Corrosion behaviour of SS 316L, immersed in simulated concrete pore solution (SCP), (saturated calcium hydroxide solution) in presence of trisodium citrate (TSC) has been investigated by polarization study and AC impedance spectra.

SS316L in SCP solution

When SS 316L is immersed in simulated concrete pure solution (SCP), the corrosion potential is –646; linear polarization resistance (LPR) is 1195399 ohm cm^2 and the corrosion current (I_{corr}) is $0.0313x10^{-6}$ A/cm^2 (Fig. 1). When 100ppm of TSC is added, the LPR value increases to 1175207 ohm cm^2; and the corrosion current value increases to $0.0436x10^{-6}$ A/cm. These observations indicate that the corrosion resistance of MS increases in presence of TSC [33-37]. This is due to the fact that the protective film formed on the metal surface in presence of TSC is not stable and is broken in simulated concrete pure solution.

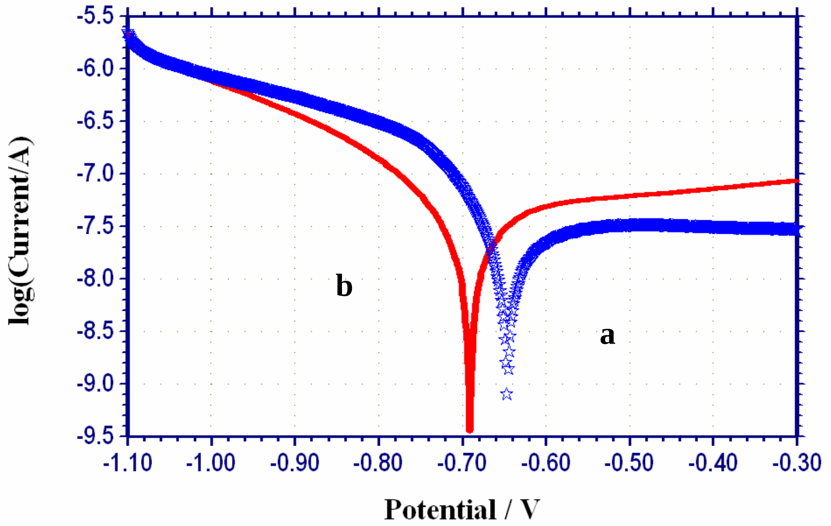

Fig 1: Polarization curves of SS316L immersed in simulated concrete pore solution (SCP) : a) SCP, b) SCP + 100ppm TSC

Thus polarization study leads to the conclusion that in presence of TSC, the corrosion resistance of SS 316L simulated concrete pore solution decreases.

AC impedance Spectra

The AC impedance spectra of SS 316L immersed in various test solutions are shown in Figs 2 to 4.

The Nquist plots are shown in Fig 2. The Bode plots are shown in Figs 3 and 4. Charge transfer resistance (R_t) and double layer capacitance (C_{dl}) values are derived from Nyquist plots. Impedance values, log (z/ohm) are derived from Bode plots. The results are summarized in Table 2.

Table 1 - Corrosion parameters of SS316L immersed in simulated concrete pour solution (Saturated calcium hydroxide solution), obtained by potentio dynamic polarization study.

System	E_{corr} mV vs SCE	b_c mV/decade	b_a mV/decade	LPR ohm cm^2	I_{corr} A/cm^2
SS316L	-646	98	673	195399	$0.0311x10^{-6}$
SS316L+TSC 100ppm	-691	162	433	1175207	$0.0436x10^{-6}$

Table 2 - Impedance parameters of SS316L immersed in simulated concrete pure solution (Saturated calcium hydroxide solution), obtained by AC impedance spectra.

System	From Nyquist plots		From Bode plots
	Rt ohm cm2	Cdl F/cm2	Impedance log(z/ohm)
SS316L	61910	8.237x10-11	5.20
SS316L+ TSC 100ppm	49250	1.036x10-10	5.072

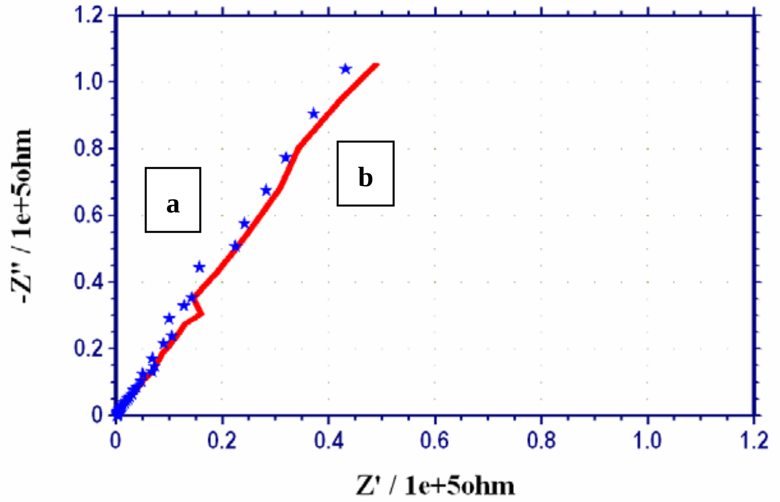

Fig 2: AC impedance spectra of SS316L immersed in simulated concrete pore solution (SCP) (Nyquist plots): a) SCP, b) SCP + 100ppm TSC

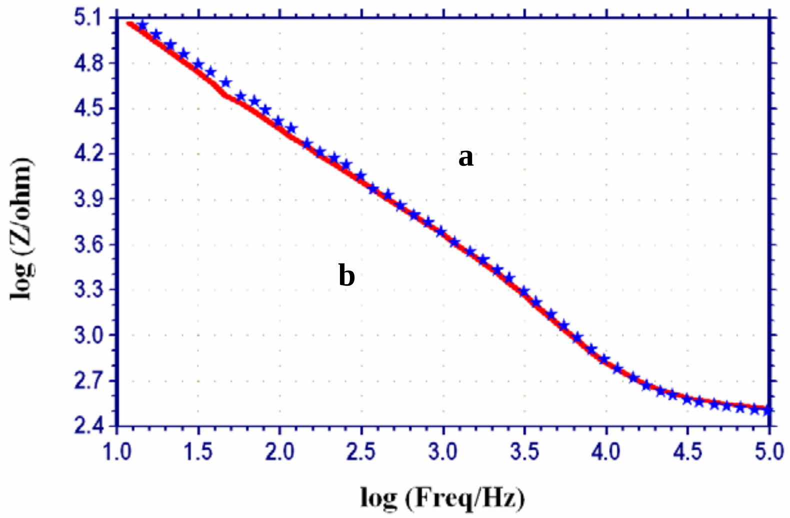

Fig 3: AC impedance spectra of SS316L immersed in simulated concrete pore solution (SCP) (Bode plots): a) SCP, b) SCP + 100ppm TSC

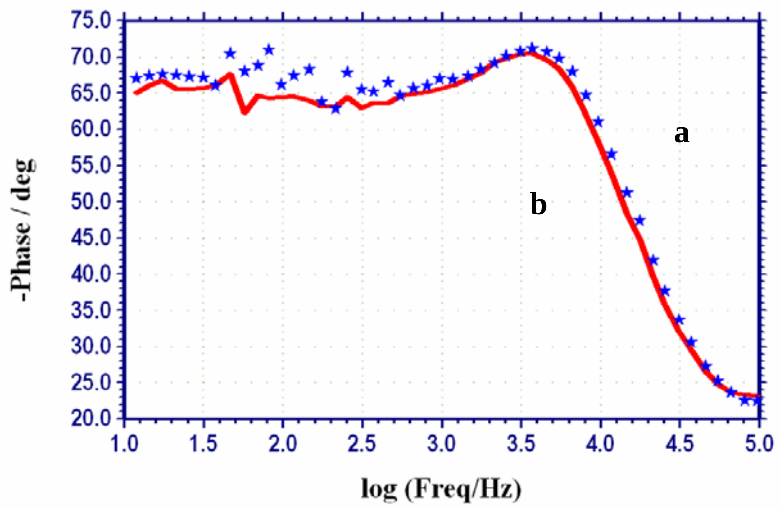

Fig 4: AC impedance spectra of SS316L immersed in simulated concrete pore solution (SCP) (Bode plots): a) SCP, b) SCP + 100ppm TSC

When corrosion rate decreases, due to formation of protective film, the charge transfer resistance value increases and double layer capacitance value decreeases; the impedance value log (z/ohm) increases [38-42]. Conversely, when corrosion rate increases, R_t value decreases and C_{dl} value increases.

SS 316L in simulated concrete pure solution (SCP)

Nyquist plots

It is observed from Table 2 that in presence of TSC, the corrosion resistance of SS 316L decreases. This is revealed by the fact that, in presence of SS316L, the charge transfer resistance decreases from 61910 to 49250 ohm cm^2 (Fig 2); The impedance value, log (z/ohm) decreases from 5.20 to 5.072 (Fig 3) and the double layer capacitance value increases from $8.237x10^{-11}$ to $1.036x10^{-10}$ F/cm^2 (Fig 2).

This result is in agreement with the result of polarization study.

Bode plots

There are two types of Bode plots

1. Impedance – Bode plots
2. Phase – Bode plots

Impedance-Bode Plots

The impedance-Bode plots are shown in Figs. 3, for SS316L system. In all the figures a general trend is obsuved. As the log (Freq/Hz) value increases, the log (z/ohm) value decreases sharply. This is characteristic of system having good inhibition efficiency due to presence of protective layer on the metal surface [43].

A small hump appears around the frequency 3.3. This may be due to presence of protective film formed on metal surface. This film may be due to iron oxide, calcium hydroxide and iron citrate complex formed on the metal surface.

Phase-Bode plots

The phase-Bode plots are shown in Fig 4 for SS316L system. In all the figures, a peak appears around 3.7. This peak is due to calcium hydroxide formed on the metal surface. When trisodium citrate is added, the protective film consists of calcium hydroxide, iron citrate and large proportion of iron oxide.

Thus, AC impedance spectra lead to the conclusion that in the presence of TSC, the corrosion resistance of SS316L in simulated concrete solution decreases.

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ABSTRACT

CORROSION RESISTANCE OF SS316L IN SIMULATED CONCRETE PORE SOLUTION IN PRESENCE OF TRISODIUM CITRATE

The corrosion resistance of SS 316L in simulated concrete pore solution, namely, saturated calcium hydroxide solution, in the absence and presence of 100ppm of trisodium citrate (TSC) has been evaluated by electrochemical studies such as polarization study and AC impedance spectra. Polarization study reveals that in presence of TSC, the corrosion resistance of SS 316L in simulated concrete pore solution decreases. AC impedance spectra reveal that in the presence of TSC, the corrosion resistance of SS 316L in simulated concrete solution decreases.

Key words: *Concrete corrosion, corrosion of SS 316L simulated concrete pore solution, trisodium citrate.*