CORROSION BEHAVIOUR OF MILD STEEL IN SIMULATED CONCRETE PORE SOLUTION PREPARED IN RAIN WATER, WELL WATER AND SEA WATER

M. Pandiarajan[a]*, P. Prabhakar[b] and S. Rajendran[a,c]

Keywords: simulated concrete pore solution, mild steel, rain water, well water, sea water, polarization study.

Concrete admixtures can be prepared in various water samples such as rain water, well water, and sea water. These waters contain various types of ions. So corrosion behaviour of mild steel immersed in simulated concrete pore solution prepared with the above water samples will vary. Corrosion resistance of mild steel in simulated concrete pore solution prepared with above water samples has been evaluated by polarization study. The corrosion resistance of mild steel in various samples of water is as follows: Rain water>Well water>Sea water. The corrosion resistance of mild steel in simulated concrete pore solution prepared in various water samples are in the decreasing order: Rain water>Well water> Sea water. This is revealed by the linear polarization resistance values and corrosion current values.

* Corresponding Authors
E-Mail: pandiarajan777@gmail.com
[a] Corrosion Research Centre, PG and research Department of Chemistry, G.T.N Arts College, Dindigul- 624 005. E.mail: pandiarajan777@gmail.com
[b] PG and research Department of Chemistry, APA College of Arts and Culture, Palani, Dindigul
[c] Corrosion Research Centre, R.V.S. School of Engineering and Technology, Dindigul- 624 005. E.mail:srmjoany@sify.com

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[1-3].

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[4-10], 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.[8,11-13] 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.

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 of mild steel in SCPS prepared in rain water, well water and sea water. A saturated solution of calcium hydroxide is used as SCP solution [26-30]. Polarization study has been used to evaluate the corrosion resistance of mild steel.

MATERIALS AND METHODS

Metal specimens

Mild steel specimen was used in the present study. (Composition (wt %): 0.026 S, 0.06 P, 0.4 Mn, 0.1 C and balance iron [31].

The composition of rainwater (collected from roof top and stored in concrete tank), well water and sea water used in the present study is given the Table 1.

Table 1.

Parameters	Rainwater	Well water	Sea water
pH	8.15	8.38	7.18
Total Dissolved Solids	273 ppm	2013ppm	39392 ppm
Electrical Conductivity	390 1/cmΩ	3110 1/cmΩ	57929 1/cmΩ
Nitrate	9 ppm	0	0
Chloride	72 ppm	665ppm	16850
Sulphate	14 ppm	14ppm	6010
Fluoride	0.2 ppm	0	0
Total Hardness as $CaCO_3$	88 ppm	1100ppm	112 ppm

 DOI: 10.17628/ECB.2012.1.238

Table 2. Corrosion parameters of mild steel immersed in simulated concrete pore solution (saturated calcium hydroxide solution),obtained by potentiodynamic polarization study.

System	E_{corr}, mV vs SCE	b_c mV/decade	b_a , mV/decade	LPR, Ω cm^2	I_{corr}, A cm^{-2}
Rain water	-822	156	287	15273	$2.887x10^{-6}$
SCPS prepared in rain water	-470	212	196	94806	4.68×10^{-7}
Well water	-833	153	302	13264	$3.329x10^{-6}$
SCPS prepared in well water	-631	194	187	35638	$1.162 x10^{-6}$
Sea water	-846	150	264	5548	$7.506x10^{-6}$
SCPS prepared in sea water	-800	159	234	6281	$6.568 x10^{-6}$

Simulated Concrete Pore (SCP) Solution

A saturated calcium hydroxide solution is used in the present study, as SCP solution. The electrodes made of mild steel wire were immersed in the SCP solution and polarization study was carried out.

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 mild steel. 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.

RESULTS AND DISCUSIONS

Corrosion behaviour of mild steel in simulated concrete pore solution (SCP), saturated calcium hydroxide solution) have been investigated by polarization study.

Polarization Study

The polarization curves of mild steel prepared in simulated concrete pore solution are shown in Figs. 1 to 3. The corrosion parameters such as corrosion potential (E_{corr}), Tafel slopes (b_c = cathodic; b_a = anodic), Linear polarization resistance (LPR), and corrosion current (I_{corr}) are given in Table 2

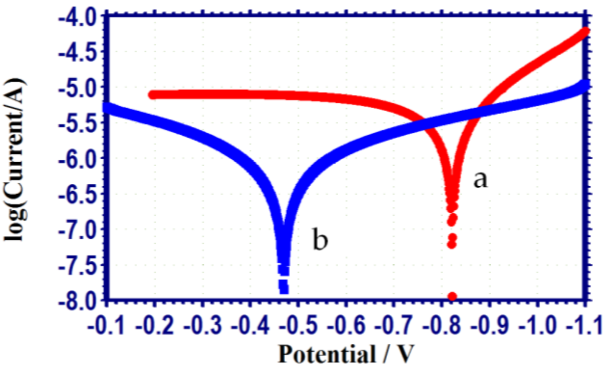

Figure 1. Polarization curves of mild steel immersed in various test solution a) Rain water; b) SCPS prepared in rain water

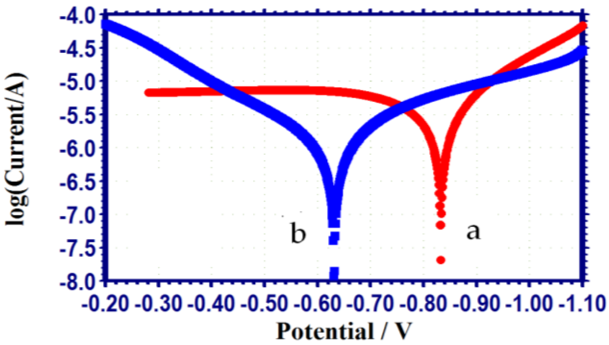

Figure 2. Polarization curves of mild steel immersed in various test solution. a) Well water. b) SCPS prepared in well water.

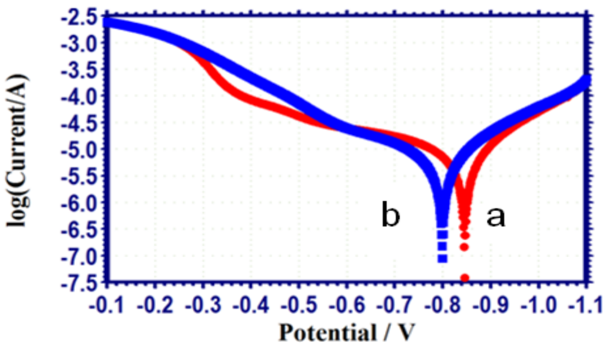

Figure 3. Polarization curves of mild steel immersed in various test solution. a) Sea water; b) SCPS prepared in sea water

It is observed from Table 2 that the decreasing order of corrosion resistance of mild steel immersed in simulated concrete pore solution prepared in rainwater, well water and sea water is as follows rain water>well water>sea water.

This is revealed by the fact that the LPR values are in the decreasing order namely 15273,13264 and 5548 ohmcm^2, further the corrosion current values increase from rainwater[$2.887x10^{-6}$ A/cm^2] to well water [$3.329x10^{-6}$ A/cm^2] and then to sea water [$7.506x10^{-6}$ A/cm^2][32-41] .

It is also observed that the corrosion resistance of mild steel immersed in simulated concrete pore solution prepared in rainwater is greater than the corrosion resistance of mild steel in rainwater alone. Similarly the corrosion resistance of mild steel immersed in simulated concrete pore solution prepared in well water is greater than the corrosion resistance of mild steel in well water, the corrosion

 DOI: 10.17628/ECB.2012.1.238

resistance of mild steel immersed in simulated concrete pore solution prepared in sea water is greater than the corrosion resistance of mild steel in sea water.

The corrosion resistance of mild steel in simulated concrete pore solution prepared in various water samples are in the decreasing order: Rain water>Well water>Seawater.

CONCLUSION

Corrosion resistance of mild steel in simulated concrete pore solution prepared with rain water, well water and sea water samples has been evaluated by polarization study.

The corrosion resistance of mild steel in various samples of water is as follows: Rain water> Well water> Sea water.

The corrosion resistance of mild steel in simulated concrete pore solution prepared in various water samples are in the decreasing order: Rain water>Well water>Seawater.

This is revealed by the linear polarization resistance values and corrosion current values. So it is concluded from these study that it is better to use rainwater to prepare concrete admixtures.

ACKNOWLEDGEMENT

The authors are thankful to their management and St.Joseph's Research and Educational Trust, Dindigul for their help and encouragement.

REFERENCES

[1]Ahmad S, *Cement Concrete Comp*.,**2003**, *25*, 459.

[2]Biezma M. V and San, J. R. C. *Corros. Eng. Sci. Techn*., **2005**, *40*, 344.

[3]Thangavel, K., *Corros. Rev*. **2004**, ***22***, 55

[4]Moreno, M., Morris, W., Alvarez, M. G. and Duffo, G. S., *Corros. Sci*., **2004,** *46*, 2681.

[5]Kumar, V., *Corros. Rev*., **1998**, *16*, 317.

[6]Maslehuddin, M., Al-Zahrani, M. M., Ibrahim, M., Al-Mehthel, M. H. and Al-Idi, S. H., *Constr. Build. Mater*., **2007**, *21*, 1825.

[7]Du, R. G, Hu, R. G., Huang, R. S and Lin, C. J., *Anal. Chem.*, **2006**, *78*, 3179.

[8]Huet, B., L'Hostis, V., Miserque, F. and Idrissi, H., *Electrochim. Acta.*, **2005**, *51*, 172.

[9]Alonso, C., Castellote, M. and Andrade, C., *Electrochim. Acta* **2002**, *47*, 3469.

[10]Poupard, O., Ait-Mokhtar, A. and Dumargue, P., *Cement Concrete Res*., **2004**, *34*, 991.

[11]Duffo, G. S., Morris, W., Raspini, I. and Saragovi, C., *Corros. Sci*., **2004**, *46*, 2143.

[12]Yeih, W. C and Chang, J. J., *Constr. Build. Mater*., **2005**, *19*, 516.

[13]Garces, P., Andrade, M. C., Saez, A. and Alonso, M. C., *Corros, Sci*., **2005**, *47*, 289.

[14]Zhou X ,Yang H. Y, Wang F. H, *Corros. Sci. Protec. Technol.*, **2010**, *22*(4), 343.

[15]Fajardo, S, Bastidas, D. M , Ryan, M. P, Criado, M., McPhail, D. S., Bastidas, J. M., *Appl. Surf. Sci.*, **2010**, *256*(21), 6139.

[16]Chen, W., Du, R. G., Ye, C.-Q., Zhu, Y.-F., Lin, C.-J., *Electrochim. Acta.,* **2010**, *55*(20), 5677.

[17]Wang, L., Zhao, Y.-L., Tiedao Xuebao (*J. China Railway Soc.,)* **2010**, *32*(4) 96.

[18]Chastre, C., Silva, M. A. G., *Eng. Struct.,* **2010**, *32*(8), 2268.

[19]Suh, K., Mullins, G., Sen, R., Winters, D., *J. Composit. Construct.,* **2010**, *14*(4) 388.

[20]Zhang, J. X., Sun, H. H., Sun, Y. M., Zhang, N., *J. Zhejiang Univ. Sci. A.*, **2010**, *11*(5), 382.

[21]Dao, V. T. N., Dux, P. F., Morris, P. H., Carse, A. H., *ACI Mater. J.*, **2010**, *107*(3), 291.

[22]Ghods, P., Isgor, O. B., McRae, G. A., Gu, G. P., *Corros. Sci.*, **2010**, *52*(5), 1649.

[23]Fan, Y. F., Hu, Z. Q., Zhang, Y. Z., Liu, J. L., *Construct. Build. Mater.*, **2010**, *24*(10), 1975.

[24]Kenny, A., Katz, A., *Adv. Mater. Res.*, **2010**, *95***,** 69.

[25]Huet, B., L'Hostis, V., Tricheux, L., Idrissi, H., *Mater. Corros.*, **2010**, *61*(2), 111.

[26]Allahkaram S.R, Khodayari, *Anti-Corros. Methods Mater*., **2008**, 55, 250.

[27]Mennucci, M. M., Banczek, E. P., Rodrigues, P. R. P., Costa, I., *Cement Concrete Compost.* **2009**, *31*, 418.

[28]Kitowski, C. J., Wheat, H. G, *Corrosion*, **1997**, *53* ,216.

[29]Hurley, M. F, Scully, J. R., *Corrosion*, **2006**, *62*, 892.

[30]Li, L., Sagues, A. A., *Corrosion* , **2004**, *60*, 195.

[31]Arockia, S. J., Rajendran, S., Garga Sri, V., Amalraj, J., A. and Narayanasamy, B., *Portugaliae Electrochim. Acta*, **2009**, *27*, 1.

[32]Kavipriya, K., Sathiyabama, J., Rajendran, S., Krishnaveni, A. *Int. J. Adv. Eng. Sci. Technol.*, **2012**, *2*(2), 106.

[33]Manimaran, N., Rajendran, S., Manivannan, M., Saranya, R. *J. Chem. Biol. Phys. Sci. Sect A.*, **2012,** *2*(2), 568.

[34]Sahayaraja, A.. Rajendran, S. *J. Electrochem. Sci. Eng.* **2012**, *2*, 91.

[35]Manimaran, N., Rajendran, S., Manivannan, M., Johnmary, S. *Res. J. Chem. Sci.* ,**2012**, *2*(3), 52.

[36]Sribharathy, V., Rajendran, S. *Int. J. Adv. Eng. Sci. Technol.* **2011**, *1*(1), 77.

[37]Anbarasi, M. C., Rajendran, S., Vijaya, N., Manivannan, M., Shanthi, T. *The Open Corros. J.*, **2011,** *4*, 40.

[38]Johnsirani, V., Rajendran, S., Sathiyabama, J., Muthumegala, T. S., Krishnaveni, A., Hajarabeevi, N. *Bulg. Chem. Commun.* **2012**, *44*(1***)***, 41.

[39]Sangeetha, M., Rajendran, S., Sathiyabama, J., Krishnaveni, A., Shanthy, P., Manimaran, N., Shyamaladevi, B. *Portugaliae Electrochim. Acta*, **2011**, *29*(6), 429.

[40]Manivannan, M., *Int. J. Adv. Eng. Sci. Technol.*, **2011**, *3*, 8048.

[41]Noreen, A., Benita, S. H., Rajendran, S., *Portugaliae Electrochim. Acta* ., **2010**, *28*(1), 1.

Received: 22.09.2012.
Accepted: 02. 10.2012.