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Corrosion inhibition of reinforcing steel in simulated concrete pore solution- An ecofriendly approach

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Abstract: The inhibition of corrosion of reinforcing steel in simulated concrete pore solution (SCPS) has been studied using mass loss, gasometric measurements, potentiodynamic polarization and impedance studies using Mezlocillin (MZN) as a green inhibitor. The studies clearly revealed that MZN acted as cathodic inhibitor. Diffused reflectance spectra confirmed the formation of adsorbed film of inhibitor on reinforcing steel in SCPS.
Keywords: Concrete Corrosion, simulated corrosion, Impedance measurements, green inhibition.

Introduction

Reinforced concrete is extensively 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 stern problem in modern society, which results in a huge economic loss[1-3].

Under normal conditions, the corrosion protection of reinforcing steel concrete can be manifested by forming a dense passive film on steel surface in concrete pore solution with high alkalinity (pH 12.5-13.5). However, the passive film can be locally impaired and the localized corrosion of reinforcing steel occurs when pH changes to acidic [4-9]. The pH of concrete composite is diminished when the concrete is exposed to sea water environment, industrial zones etc., Hence the pH value of concrete pore solution is one of the most important parameters affecting the corrosion behavior of reinforcing steel in concrete. Recently several inhibitors have been used to retard the corrosion of reinforcing steel in concrete which are toxic and expensive [10-14] .So the development of less toxic and inexpensive inhibitors for combating the corrosion of reinforcing steel in concrete is an emerging field of investigation and research in this direction is still at scanty level. In this paper, the authors have attempted to make use of Mezlocillin (MZN), a green inhibitor to protect the corrosion of reinforcing steel in simulated concrete pore solution. Mezlocillin is a broad-spectrum penicillin antibiotic. It is active against both Gram-negative and some Gram-positive bacteria for curing antibacterial infections in stomach and urinary track for humans.

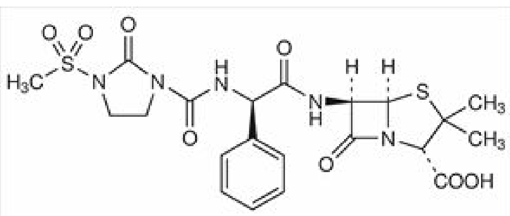

Figure 1.Structure of Mezlocillin

As far as we know no concrete report has been published so for using MZN in simulated concrete pore solution with aid of mass loss, gasometry, potentiodynamic polarization, impedance measurements and diffuse reflectance spectra. The structure of the Mezlocillin (MZN) is shown in the figure.1. Different concentrations of green inhibitor were prepared and their inhibition efficiencies in simulated concrete pore solution were investigated.

Experimental

Reinforcing steel specimens of compositions, C = 0.08%, P = 0.07%, Si = O%, S = 0.02%, Mn = 0.41% and Fe remainder, and of size 4 x 1 x 0.020 cm were used for mass loss and gasometric studies. The mass loss study was carried out at room temperature for three hours in simulated concrete pore solution(SCPS). The SCPS was prepared by dissolving the calculated quantity of 1.5 gram of Calcium hydroxide and 35 g of sodium chloride in one litre of rain water or double distilled water. The inhibition efficiency (IE %) was determined by the following equation, I.E (%) = $(W_0 - W_i / W_0)$ X 100

Where W_0 & W_i are the mass loss values in the absence and presence of the green inhibitor. A reinforcing steel cylindrical rod of the same composition as above and embedded in araldite resin with an exposed area of 0.283 cm^2 was used for potentiodynamic polarisation and AC impedance measurements.

The green inhibitor preliminarily screened by a weight loss method described earlier[15]. Both cathodic and anodic polarisation curves were recorded in SCPS potentiodynamically(1 mV s^{-1}) using corrosion measurement system BAS Model: 1OOA computerised electrochemical analyzer (made in West Lafayette, Indiana) and PL-10 digital plotter (DMP-40 series, Houston Instruments Division). A platinum foil and Hg/Hg_2Cl_2/3.5%NaCl were used as auxiliary and reference electrodes respectively. Double layer capacitance (Cdl) and charge transfer resistance values (R_{ct},) were obtained using AC impedance measurements [10-18]. The surfaces of corroded and corrosion inhibited mild steel specimens in SCPS solution were examined by diffuse reflectance studies in the region 200- 700 nm using U-3400 spectrometer (UV-VIS-NIR Spectrometer, Hitachi, Japan).

Results and Discussion

Mass loss and Gasometric measurements

Table 1. Values of inhibition efficiency for the corrosion of reinforcing steel in SCPS in the presence of different concentrations of MZN obtained from mass loss and gasometric measurements.

Concentration of Green Inhibitor (ppm)	Inhibition efficiency (%)	
	Mass loss Studies	Gasometric measurements
0	---	---
50	85	84.6
100	92.2	92.0
150	97.4	97.2

Table 1 indicates the results of inhibition efficiency for different concentrations of Mezlocillin (MZN) for the corrosion of reinforcing steel in simulated concrete pore solution obtained from mass loss and gasometric measurements. It is found that the green compound retards the corrosion of steel effectively in SCPS. The existence of 2-oxo-imidazolidine and methyl sulfonyl groups in the inhibitor molecule which shows inductive (+I) effect. This may enhance the electron density on the sulfur atom that leads to better performance than the other sulfur containing inhibitors..

A definite correlation between the values of inhibition efficiency calculated by mass loss and gasometric methods is observed.

The corrosion kinetic factors such as Tafel slopes (b_a and b_c),corrosion current (I_{corr}) and corrosion potential (E_{corr}) and inhibition efficiency obtained from potentiodynamic polarization curves for reinforcing steel in SCPS containing various concentrations of green inhibitor are given in table 2.

Potentiodynamic polarization studies

Table 2: Corrosion kinetic parameters of reinforcing steel in SCPS in the presence of different concentrations of MZN obtained from potentiodynamic polarization studies.

Con. MZN	E_{corr} (mV vs SCE)	I_{corr} (µA cm-2)	b_a (mV dec-1)	b_c (mV dec-1)	IE (%)	θ
0 PPM	-400.12	290.2	196.2	210.0	-	-
50 PPM	-376.28	43.7	168.5	189.0	84.9	0.85
100 PPM	-360.82	23.22	143.2	163.4	91.9	0.92
150 PPM	-345.43	8.71	113.3	94.0	96.99	0.97

The values of b_a, b_c and I_{corr} are very much similar to those reported earlier [16,17]. Further it is established that increasing concentrations of Mezlocillin (MZN) increased the values of both b_a and b_c ,but the values of b_c are enhanced to a greater extent. So the inhibition of corrosion of reinforcing steel in SCPS is under cathodic control. Values of E_{corr} is moved to less negative values in the presence of different concentrations of green inhibitor. This can be ascribed to the formation of closely adherent adsorbed film on the steel surface.

Impedance measurements

Corrosion inhibition of reinforcing steel in simulated concrete pore solution with and without Mezlocillin (MZN) was investigated by electrochemical impedance

Table 3.Impedance values for the corrosion corrosion of reinforcing steel in SCPS in the presence of different concentrations of MZN .

Concentration of Inhibitor (ppm)	Simulated concrete pore solution	
	Charge Transfer resistance (R_{ct}) Ohm.cm^2	Double layer capacitance (C_{dl}) µF.cm^{-2}
Blank	30.7	171.3
50	80.2	109.5
100	117	83.2
150	152	43.2

Spectroscopy measurements and the results are presented in table 3. At all concentrations range of MZN, large capacitive circles at higher frequency range followed by small capacitive loops at lower frequency range are obtained. The diameter of the circles increased with increase in green inhibitor concentration. The higher frequency capacitive loop is due to the adsorption of inhibitor molecule. Similar observations were reported by Gu Hough et al [16] and others [17-19] for the corrosion inhibition of mild steel in acidic media by Ampicilin drug and thio compounds.

Also the values of R_{ct} are found to increase with increase in concentrations of green inhibitor in SCPS whereas values of C_{dl} have reduced considerably. This can be attributed to the strong adsorption of Mezlocillin (MZN) on the reinforcing steel surface.

Diffused Reflectance Studies

The formation of thin film on the surface of reinforcing steel immersed in SCPS is realized by UV reflectance studies carried out using spectrophotometer in different concentrations of Mezlocillin (MZN) with different mild steel specimens. The reflectance curves for polished specimen, specimen dipped in simulated concrete pore solution and different concentrations of green inhibitor are shown in the figure 2. The percentage of reflectance is maximum for polished reinforcing steel and it gradually decreases for the specimen dipped in simulated concrete pore solution. This observation reveals that the change in surface characteristic is due to the corrosion of reinforcing steel in corroding medium. When compared with uninhibited solution, the reflectance percentage increased as the concentration of the green inhibitor increased. This can be ascribed to the increase in film thickness formed on reinforcing steel surface [19].

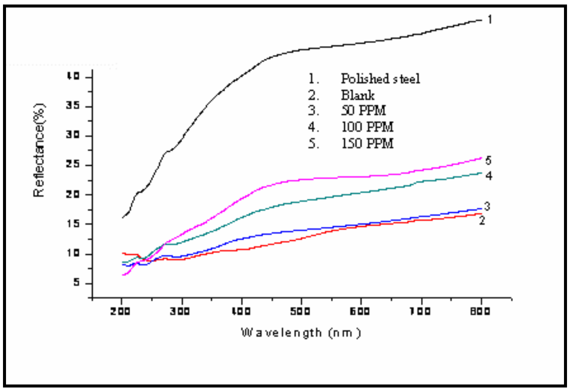

Figure 2. UV Reflectance curves for reinforcing Steel in simulated concrete pore solution with different concentrations of Mezlocillin.

Conclusions

1. Mezlocillin (MZN) inhibits the corrosion of reinforcing steel effectively in simulated concrete pore solution.
2. The inhibition of corrosion of reinforcing steel in SCPS, by the green inhibitor is under cathodic control.
3. R_{ct} and C_{dl} values obtained from impedance measurements confirm the better performance of the Mezlocillin .
4. 4. UV –reflectance studies reveal the mere adsorption of the green inhibitor on the reinforcing steel surface accounted for the corrosion inhibition of steel in simulated concrete pore solution.

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