CORROSION OF STEEL REINFORCEMENTS IN CONCRETE IMMERSED IN DIFFERENT ENVIRONMENTS

By

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ABSTRACT

The electrochemical corrosion behaviour of mild steel and medium carbon steel embedded in concrete immersed in sodium chloride, sodium sulphide and seawater media was studied by electrode potential and pH measurements. A digital voltmeter with zinc rod reference electrode was used to measure the electrode potential while pH meter was used to measure the pH values. It was observed that corrosion potential was greater in mild steel concrete reinforcement in all the media. Seawater was also found to be most aggressive to both mild steel and medium carbon steel concrete reinforcements. This was closely followed by 1M NaCl, 0.5M NaCl, and 1M Na_2SO_3 in that order.

Keywords: *Corrosion, concrete, passivation, reinforcements, mild steel, medium carbon steel.*

1.0 INTRODUCTION

Corrosion of embedded steel in reinforced concrete structures leading to cracking and subsequent spalling is now recognized as a major problem confronting the construction industry in almost all parts of the world. This problem is severe in coastal and offshore reinforced concrete structures because of the presence of aggressive chloride ions in seawater. Also, many distress in concrete bridges paralleled increasing use of chloride salts as a de-icing agent on roads, bridges and packing structures (Stark, 1989).

Carbonation has been identified as another major cause of degradation of concrete reinforcement by corrosion (Montani, 1997; Emmons, 1994 and Parker, 1997). It is a phenomenon that occurs as a result of carbon dioxide diffusing into the concrete pores and react with the calcium hydroxide to form calcium carbonate. Carbonation is highly dependent on the permeability of the concrete (Parker, 1997).

However, various efforts have been directed towards the design of new structures to reduce or completely eliminate corrosion of concrete reinforcement. Some of these methods include the use of increased concrete cover, using concrete of reduced permeability or replacing steel with entirely different materials such as galvanized rebars and epoxy coated rebar, among many other potential solutions (Andrade et al, 1994). Albeit, carbon steels still remain the best reinforcing materials considering their cost and strength.

Therefore, the electrochemical corrosion behaviour of mild and medium carbon steel rods used as concrete reinforcement under some selected media is investigated in this work. Seawater was used to simulate the marine environment while sodium sulphide was used to represent an industrial or chemical-industry environment.

Sodium chloride was used because of the aggressive corrosion reaction (due to the Cl^- ion) in steel-reinforced concretes (Short and Page, 1981) and (Holden et al., 1983). Other objective of this work is to compare the corrosion behaviour of these steels embedded in concrete immersed in these environments. This research is expected, among other things, to assist in predicting the lifespan of reinforced concrete structures so as to protect their integrity.

2.0 MATERIALS AND METHOD

Eight concrete test specimens were cast by mixing cement, sand and gravel in the ratio 1:2:4 by mass. Four concrete slabs reinforced with 11mm diameter mild steel whose chemical composition is shown in Table 1 were prepared using the procedure and specifications fully described in (Afolabi, 2005). The remaining four concrete slabs were reinforced with medium carbon steel having chemical composition shown in Table 1. Each of the reinforced concrete specimens was partially immersed in 0.5M of NaCl, 0.5M Na_2SO_3 and seawater media. The electrode potential of each specimen was recorded at three-day interval for sixty days using a high impedance digital voltmeter with zinc rod reference electrode as shown in Figure 1. The measured potentials were converted to saturated calomel potential using the relation: Electrode Potential mV (SCE) = (E_{Zn} – 1030) (Hibbert and James, 1984; Tutti, 1982) where E_{Zn} is the measured electrode potentials of zinc reference electrode. The pH values of the media were taken with pH meter.

3.0 RESULTS AND DISCUSSION

Figures 2 and 3 show the respective plots of electrode potential versus exposure time for mild steel and medium carbon steel reinforced concrete immersed in 1M NaCl, 0.5M NaCl, 0.5M Na_2SO_4 and seawater media. The Figures indicate electrode potential fluctuations throughout the exposure period (60 days) in all the media. This behaviour is due to continuous protective oxide film build-up and breakdown on the concrete reinforcement as a result of ingress of the respective medium through the pores of the concrete to the reinforcing steels. This variation in electrode potential with exposure time is termed "electrochemical noise" (Cottis et al., 1997) and (Millard, 1991).

According to ASTM (1991), with saturated calomel reference electrode an electrode potential of above -120m indicates low (10%) risk of corrosion, the range -126 to 276mV potential indicates intermediate corrosion risk, potential between -276 and -426 mV shows high (<90%) risk of corrosion while electrode potential less than -426mV indicate severe corrosion. Based on these criteria, it could be observed that both mild steel and medium carbon steel reinforcements (Figs. 2 and 3) produced curves that are mostly stable in the severe corrosion region in all the media. This further shows that all the media have a degree of corrosiveness towards the reinforcements.

It is however noticed that seawater is the most corrosive of all media. This is due to the presence different reacting anions and cations such as Cl^- , SO_4^{2-}, Br^-, and substantial concentrations of magnesium chloride in addition to the chloride constituent i.e. sodium chloride. This facilitates more breakdown of the protective film on the steels embedded in the concrete which culminated into more negative values of the electrode observed for seawater medium in the Figures. 1M NaCl is the second most aggressive medium and is followed by 0.5M NaCl. Sodium chloride aids the conductivity within the concrete pores as well as destroying the protective film around the embedded steels.0.5M NaCl is the next corrosive medium after 1.0M NaCl. This supports Hausmann's (1967) findings that a more concentrated solution is more corrosive than a diluted one. Sodium sulphide medium has the lowest depassivating effect on the embedded steels. This is not unconnected with the weak nature of the sulphurous acid produced by the reaction of the solution with water.

$Na_2SO_4 + 2H_2O = 2NaOH + H_2SO_3$ ... (1)

This acid could not easily depassivate the passive film on the concrete reinforcements. It could also be observed from the Figures that the mild steel reinforced concrete test specimen shows a slightly higher corrosion resistance than the specimen reinforced with medium carbon steel. This corroborates the findings of Borode and Okpala (1999) cited in Okpala and Jombo (2004) that the higher the carbon content in carbon steels the greater is its susceptibity to corrosion. Even higher silicon and manganese contents in the medium carbon steel were not able to militate its corrosion susceptibility as predicted by Trethwey and Chamberlain (1996).

In the same vein, it could be observed (Figs 4 and 5) that the pH of the mild steel and medium carbon steel concrete reinforcements almost remain steady between 12 and 14 within the first fifteen days of exposure. This indicates that the reaction taking place between the corrosive media and the concrete pores have not affected the overall concentration of the corrosive media during this period. These pH values show steady decrease till the remaining part of the exposure period and support the findings of Afolabi (2005). At this value, the depassivating effect of the various media on the embedded steels has shifted the concentration of the media to acidic region. This change in media concentration further aids the depassivating action of the media on the reinforcing steels as shown in Figures 2 and 3.

4.0 CONCLUSION

1. The mild steel and medium carbon steel reinforcements are stable in the severe corrosion region in all the four media.

2. All the media are corrosive to the embedded mild and medium carbon steels in concrete. The degree of their aggressiveness is in the order: Na_2SO_3 < 0.5M NaCl < 1M NaCl < Seawater.

3. Medium carbon steel reinforcement is more susceptible to corrosion than mild steel reinforcement in all the media.

4. The depassivating effect of the media on the embedded steels altered their concentrations thereby making them more acidic, hence more aggressive to the reinforced steels.

5.0 REFERENCES

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Table 1: Chemical composition of mild and medium carbon steel samples

Chemical Composition (%)	Fe	C	Si	S	P	Mn	N	Mo	Cu	Cr
Mild Steel	98.72	0.18	0.2	0.01	0.49	0.12	0.04	0.02	0.2	0.02
Medium Carbon Steel	98.14	0.38	0.22	0.04	0.03	0.78	0.08	0.02	0.19	0.12

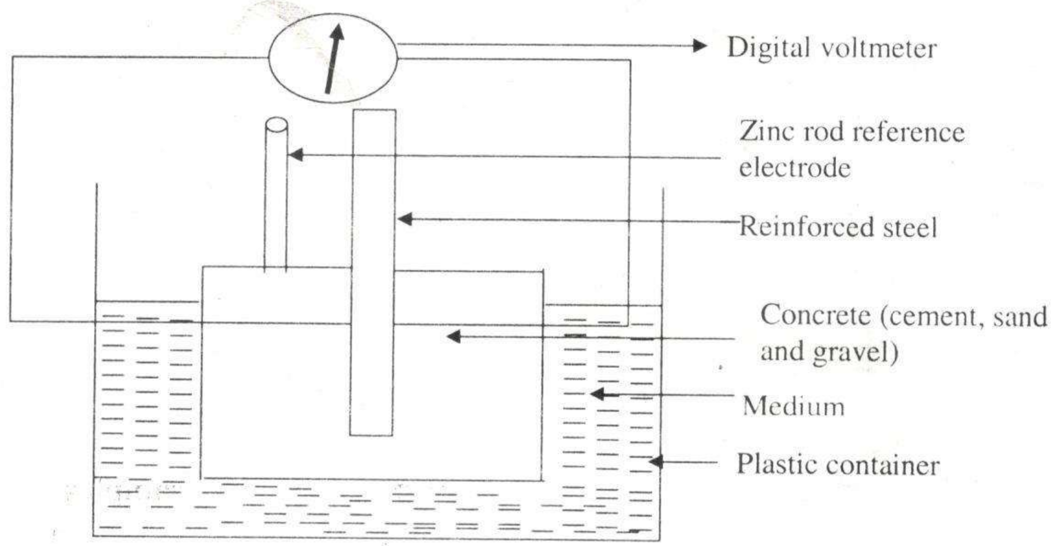

Fig.1: Experimental set-up showing electrode potential measurement.

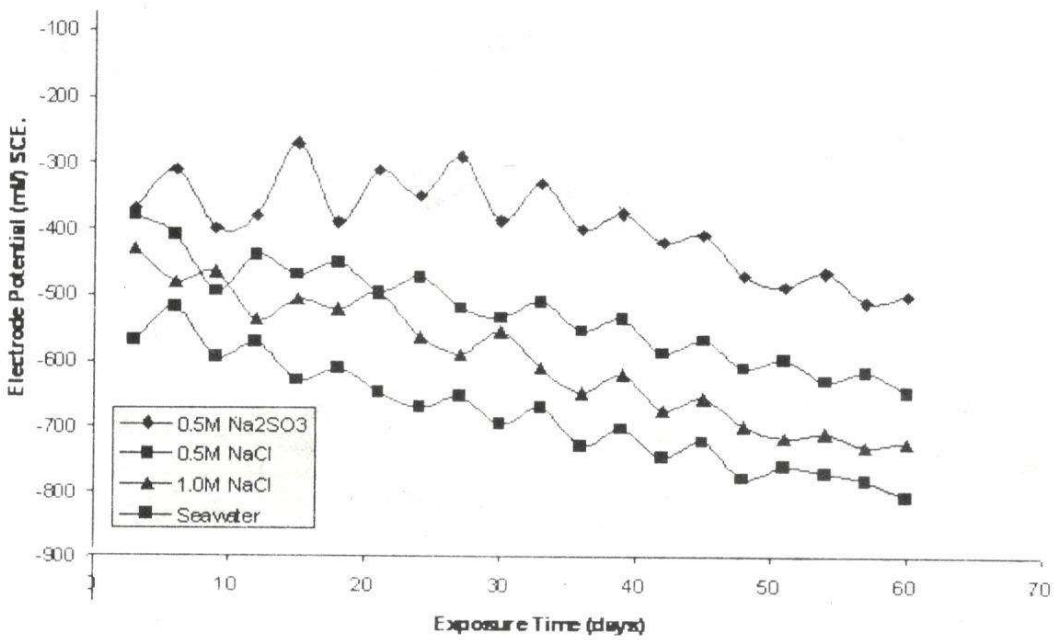

Fig 2: Electrode Potential Vs Exposure Time for Mild Steel Reinforced Concrete Immersed in Different Environments.

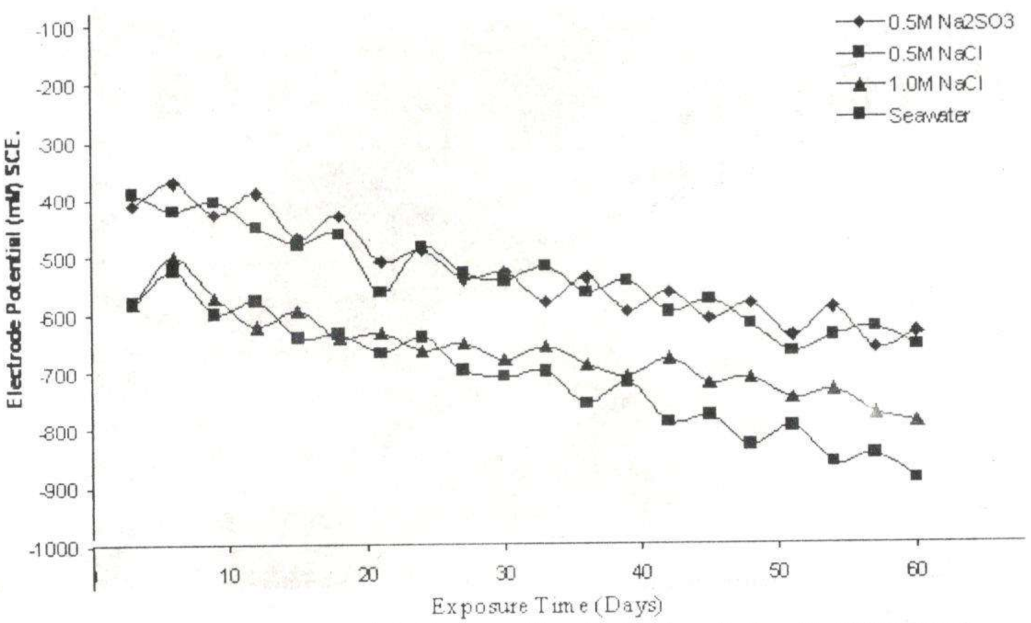

Fig. 3: Electrode Potential Vs Exposure Time for Medium Carbon Steel Reinforced Concrete Immersed in Different Environments.

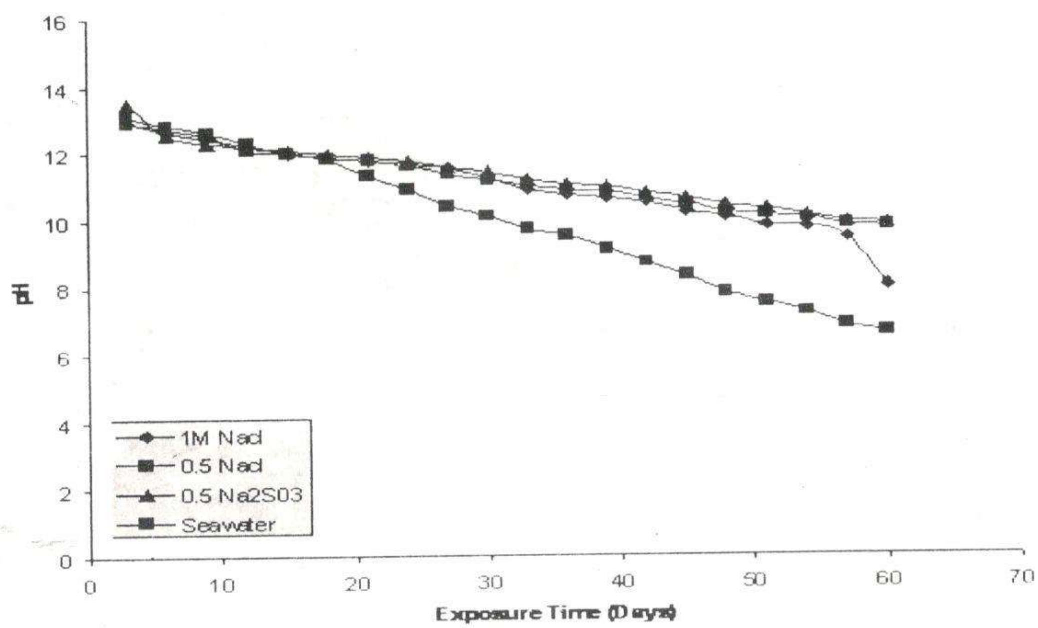

Fig 4: pH Vs Exposure Time for Mild Steel Reinforced Concrete Immersed in 0.5M NaCl, 1.0M NaCl, 0.5M Na2SO3 and Seawater

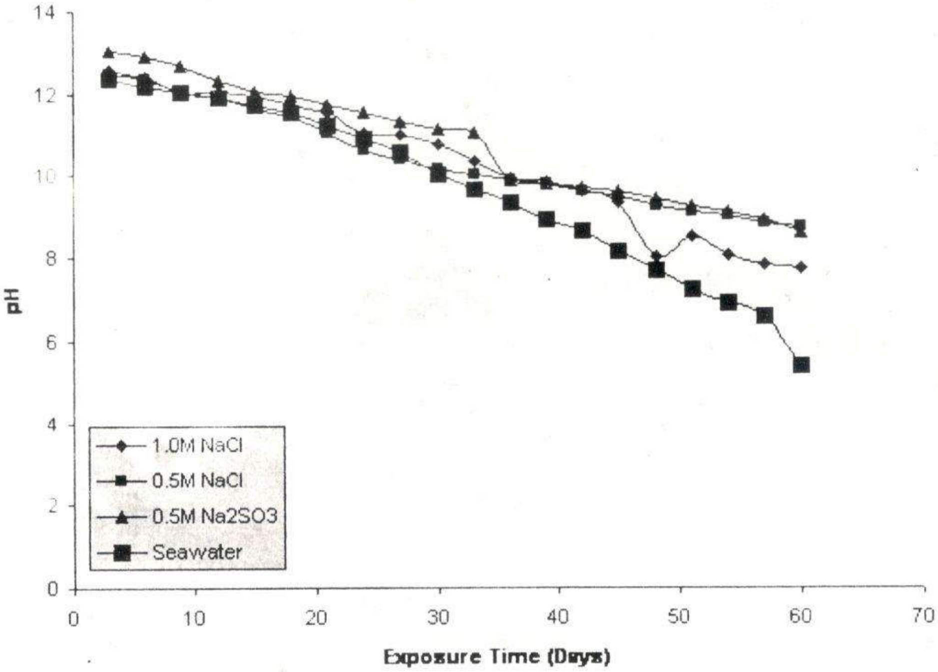

Fig 5:pH Vs Exposure Time for Medium Carbon Steel Reinforced Concrete Immersed in 0.5M NaCl, 1.0M NaCl, 0.5M Na2SO3 and seawater.