CORROSION PERFORMANCE OF DIFFERENT REINFORCEMENT BARS USED IN CONCRETE STRUCTURES

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Abstract – *The durability of concrete structures and their long-term performance have emerged over the last few decades which becomes a major concern for all. It has been known that steel rebars embedded in concrete are in the passive state, due to the basic nature of concrete. Thus, the steel is not subjected to corrosion and ensures its durability. However, problems may start to occur within few years of service. This could be due to durability but not because of the structural problem. This durability problem is because of carbonation of the concrete or the presence of chloride ions. Because of these factors, the passivity of steel has been destroyed and corrosion commenced. As a result of these effects, the service life of reinforced concrete structures has been reduced and finally the structures have been collapsed. Though a wide variety of protection methods are adopted to extend the service life of concrete structures, corrosion monitoring of the reinforcement bars embedded in concrete is very much important to assess the corrosion condition and to take appropriate remedial measures for preventing the premature failure of the concrete structures. In this paper attempts have been made to study the corrosion behaviour of two different reinforcement bars namely mild steel and stainless steel rebars exposed in simulated concrete environment and the results shows that stainless steel rebars perform better when compared to the mild steel bars.*

Key Words: **Simulated concrete environment, cement extract, Impressed voltage, Anodic polarization, reinforcement bars, chloride.**

1.INTRODUCTION

Concrete is one of the most versatile and widely used construction materials throughout the world. Reinforced concrete structures withstand the environmental conditions throughout its life-span if properly prepared and placed. The steel embedded in concrete structure whether as reinforcement or prestressed tendon, being ferrous material, is prone to corrosion which cannot be totally eliminated. Corrosion can be fast or slow [1]. Corrosion related distress is not confined to India but have been experienced all over the world. All developed countries have carried out necessary preventive measures including revision of the concrete codes by incorporation of suitable durability practices in seventies and eighties. Corrosion of reinforcing steel is the leading cause of deterioration of our concrete structures. When steel corrodes the resulting rust occupies a greater volume than the steel [2]. This expansion creates tensile stresses in the concrete, which can eventually cause cracking, delamination and spalling of concrete and reduction of cross-section of steel. Due to reduction of cross-section of steel, the load carrying capacity is reduced. In addition to that reduction of elongation properties and fatigue strength also occurs. As a result, the service life of our valuable concrete structures gets reduced. Corrosion control is achieved by recognizing and understanding corrosion mechanisms, by using corrosion-resistant materials, proper designs using protective systems, devices, and treatments. In addition to protective measures, periodic corrosion monitoring is essentially needed for assessing the present condition of prestigious concrete structures. Various techniques for detecting and measuring corrosion will provide data on the causes, detection or rate of corrosion [3]. Accordingly, corrosion monitoring can give more complete information of changing condition of a structure in time [4].

Many techniques are available for monitoring corrosion of steel in concrete structures, but none of them appears to be foolproof. Each technique has its own limitation. Techniques like potential measurements and concrete resistivity measurements do not give corrosion rates. Techniques like linear polarisation and noise analysis can give quantitative formation, provided proper instrumentation is used. Corrosion probes based on electrical resistance are to be installed at the time of construction itself. However, following techniques are widely adopted in RCC structures.

1.1 Open circuit potential measurements

The principle involved in this technique is essentially measurement of corrosion potential of rebar with respect to a standard reference electrode, such as saturated calomel electrode. The steel rebar in concrete structure should be accessible in a few locations for giving electrical connections. The positive terminal of high impedance voltmeter is connected to exposed rebar and negative terminal to reference half-cell. The surface of concrete is divided into number of grids. The reference electrode is moved along the nodal points and the corresponding potentials are recorded. As per ASTM C876, the probability of reinforcement corrosion is as follows [5].

Table-1: Probability of corrosion

mV vs. SCE	mV vs. CSE	Probability of corrosion
More –ve than -275	More –ve than -350	>90
Between -275 & -125	Between -350 & -200	Uncertain
More +ve than -125	More +ve than -200	<10

1.2 Polarisation resistance technique

Among the various electrochemical techniques, for evaluation of instantaneous corrosion rate in the laboratory is the resistance polarisation method. This technique was developed by stern and Geary in 1957. The principle involved in this technique is that a linear relationship exists between potential and applied current, as potentials are slightly shifted from the corrosion potential [6].

1.3 Surface potential measurements

During corrosion process, electric current flows between the cathodic and anodic sited through the concrete and this flow can be detected by measurement of potential drop in the concrete. Hence, surface potential measurement is used as a non destructive testing for indentifying anodic and cathodic regions in concrete structure and indirectly detecting the probability of corrosion rebar in concrete. Two reference electrodes are used for surface potential measurements [7].

1.4 Electrochemical noise analysis

Electrochemical noise technique is an emerging technique for monitoring corrosion of reinforced concrete structures. This technique enables information on the mechanism and rate of corrosion processes at areas identified in concrete structures. Flow amplitude variation of the corrosion potential of steel in concrete is measured to obtain a noise data as a record of a potential fluctuation in the form of power spectra. The measurement interval is usually between 2-10 seconds depending upon the frequency range. In this paper attempt has been made to study the corrosion behaviour of mild steel rebars and stainless steel rebars under simulated concrete environment.

2 EXPERIMENTAL

In this study simulated concrete environment as cement extract and cement extract + NaCl were prepared. Triplicate specimens of mild steel and stainless steel rebars were used. The diameter of the rebar is 10mm. Three different tests were adopted to ensure the corrosion performance of rebar. They are Impressed voltage test, Anodic polarization study and Potential Time study. Before conducting the experiments, rebars were pickled. For impressed voltage test, 7% NaCl solution is prepared. For the other two studies simulated concrete environment with and without chloride were made.

2.1 Preparation of cement extract

Simulated concrete test solution as cement extract was prepared with PPC. At first 100 grams of PPC was weighed using digital balance and transferred to the conical flask. Then 200ml distilled water was measured using measuring flask, added to the cement and thoroughly mixed. Then the conical flasks were placed on the electronic shaker. It was allowed to run about one hour. Then the mixed solutions were filtered using filter paper. This filtered solution is said to be cement extract. The pH of the cement extract is 12.40. This cement extract was used throughout the studies. Similarly known amount of NaCl is added to cement extract to create cement extract + NaCl simulated environment.

2.2 Impressed voltage test

Impressed voltage test is to assess the corrosion activity of the mild steel and stainless steel rebars by providing the constant voltage of 2V and observing the current variations under sea water condition i.e. 7% NaCl solution. Respective identical rebars were used as anode and cathode.

2.3 Anodic polarization study

This study is to identify the tolerable limit of mild steel and stainless steel rebars by impressing constant current and observing the potential under simulated condition of with and without chloride. In this test a constant current density of 290μA/cm^2 has been applied. Rebars were used as the working electrodes. Saturated calomel electrode and platinum foil were used as the reference electrode and auxiliary electrode respectively.

2.4 Potential study

Potential study is to analyze the potential time behavior of mild steel and stainless steel rebars under simulated concrete environment in the presence and absence of chloride. Saturated calomel electrode was used as the reference electrode. Rebars were used as the working electrode. In this test 10000 ppm of chloride solution was taken as the simulated environment.

3. RESULTS AND DISCUSSIONS

The results of corrosion behaviour of mild steel and stainless steel rebars were shown below.
The results obtained from impressed voltage test are described in Figure-1. Uniform corrosion was observed in the mild steel rebar at the end of the test period and found an average current value of 6.1A. Moreover pitting corrosion was observed in the stainless steel rebar at the end of the test with the constant current of 1.9A was observed throughout the test period.

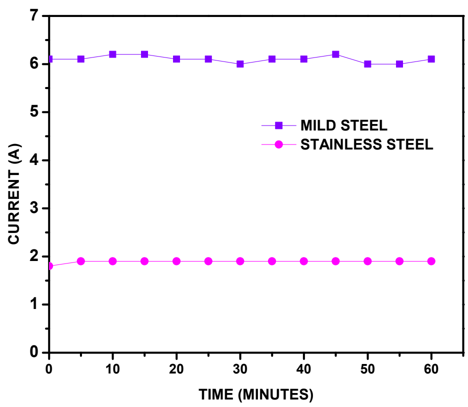
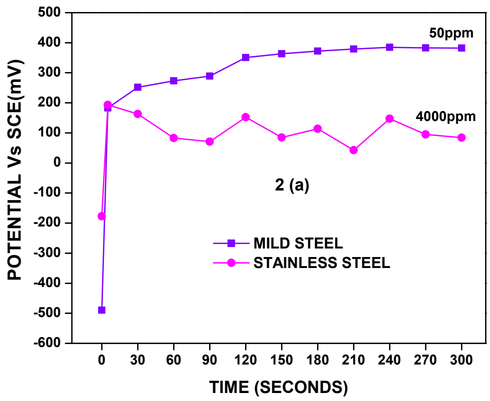


Figure-1: Time Vs Current of mild steel and stainless steel rebars.

In anodic polarization test the results are given in Figure-2 It can be seen that mild steel rebar can tolerate only 50ppm whereas stainless steel rebar tolerate 4000ppm of chloride. Figure-2(a) shows the variation in potential with time during the study. Figure-2(b) gives the tolerable limit of chloride for each rebar. From figures it can be seen that mild steel rebar has high potential values than stainless steel rebar.



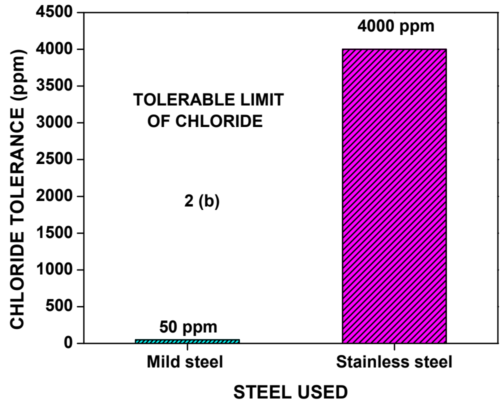
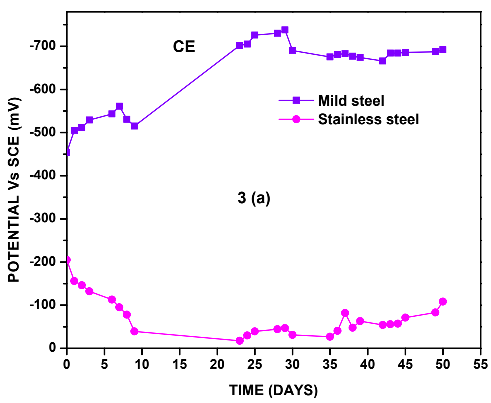


Figure 2: Anodic polarisation study on mild steel and stainless steel rebars

Potential time behaviour of mild steel and stainless steel rebars are shown in Figure-3. Figure 3(a) shows the potential time behaviour of mild steel and stainless steel rebars in the cement extract without chloride. It can be seen from the figure that potential values have increased up to 7 days and after slight fluctuation with time the potential values again increased from 23rd day. After 30 days the potential values again got increased. The potential lies between -400 mV to -740 mV. The potential values of Stainless steel rebar in the cement extract alone have decreased up to 23 days and after that the values got increased. The potential values vary between -15 mV to -200mV. Fig 3(b) shows the potential time behaviour of mild steel and stainless steel rebars in the cement extract with chloride. In this condition the potential values of mild steel rebar got increased up to 7 days and then decreased up to 20 days of exposure. Later it got fluctuated over time. Their potential values lies between -490 mV to -700 mV. Whereas in the stainless steel rebar, even though there is a fluctuation in potential values with time, they vary between -100 mV to -280 mV only.



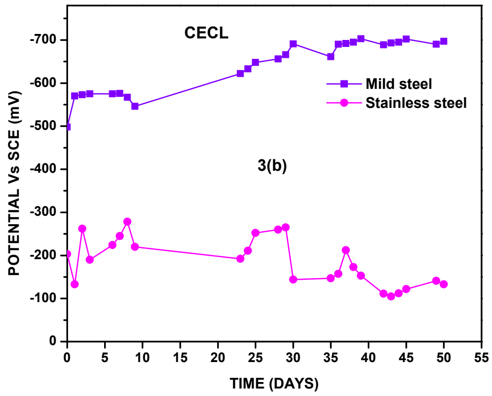


Figure- 3: Potential Time behaviour of mild steel and stainless steel rebar with and without chloride

4. CONCLUSIONS

[1] From impressed voltage test, it is concluded that stainless steel rebar has more resistance than the mild steel rebar since the current value is less in stainless steel rebar comparing the mild steel rebar.

[2] Anodic polarisation study concludes that tolerance value of mild steel is very less comparing the stainless steel rebar. Hence, stainless steel rebar is better tolerant comparing the mild steel.

[3] Potential time behaviour of mild steel rebar and stainless steel rebar concludes that more negative values were observed in mild steel rebar compared to stainless steel rebar.

[4] From the test results it is inferred that irrespective of chloride condition stainless steel rebar exhibit very low potential values than the mild steel rebar.

[5] From the overall studies it is concluded that stainless steel rebar performs better when compared to mild steel rebar.

6. REFERENCES

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