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Correlation between Half-Cell Potential and Corrosion Current Density for Corrosion Assessment of Rebar in RC Structures

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Abstract: **-- Corrosion of steel embedded in reinforced concrete (RC) structures is a major problem resulting in reducing the service life and durability of RC structures and causing early failure of the structure. Corrosion also costs significantly for inspection and maintenance of deteriorating RC structures. Hence, for preventing premature failure of RC structures, assessment of reinforcement corrosion is of significant importance. Practically, based on visual observation or using qualitative electrochemical techniques like half-cell potential measurement, the level of corrosion can be evaluated. Since for existing structures, it difficult to calculate the rate of corrosion using quantitative electrochemical techniques like Tafel extrapolation technique, linear polarization technique etc. as the instruments require direct contact with corroding steel rebar. Such measurements require damaging the small area of the structure and besides this, the potential/current scans applied to reinforcing steel during measurements may accelerate the corrosion process. Hence it is essential to corroborate relation between qualitative and quantitative techniques used for measurement of corrosion. The present paper aims to establish the relation between two electrochemical techniques namely, half-cell potential and Tafel extrapolation technique. For experimental work, RC slabs reinforced with four steel bars were cast and subjected to accelerated corrosion. The electrochemical measurements were recorded every day till the completion of tests to establish the relation between Half-cell potential and corrosion current density values obtained from Tafel plots.**

Keywords**: - Corrosion, Reinforced concrete structure, half-cell potential, Tafel extrapolation technique.**

I. INTRODUCTION

The phenomenon of corrosion of reinforcement bar in concrete is a time dependent process. Under severe environmental conditions also, it takes years for the steel reinforcement to be corroded and to cause deterioration of reinforced concrete (RC) structures. In recent years an increased research effort has been focused upon corrosion of reinforcing steel in concrete and upon techniques whereby such damage can be reduced. During the corrosion process, the increase in the volume of rust products exerts stresses within the concrete [1]. This weakens the bond between the steel and concrete, reducing the bearing capacity, serviceability and ultimate strength of concrete elements within the structure. Due to such deterioration, it has become necessary to measure the corrosion in qualitatively and quantitatively. As corrosion rate is complicated effort to calculate on site for existing structure. Hence it is essential to corroborate relation between qualitative and quantitative techniques used for measurement of corrosion. The present paper aims to establish the relation between two electrochemical techniques namely, Half-cell Potential and Tafel extrapolation technique. Analysis of measured data is based on the experimental investigation.

II. EXPERIMENTAL PROCEDURE

2.1 Specimen preparation

Initially, physical properties of cement, fine aggregate and course aggregate was determined. Based on these results mix design was performed for M20 grade of concrete as per IS 10262-2009 and obtained proportion was 1: 2.59: 2.1 with water cement ratio 0.5. All specimens were cast for M20 grade of concrete. Ordinary Portland cement of 55grade was used .Natural sand confirming to Zone II as per IS 383-1970 was used as fine aggregate. Aggregate nominal size of 10mm used as Course aggregate. RC rectangular specimen was cast as shown in figure no 1. Specimen size of 500mm in length, 300mm in width and 64 mm in thickness with 20Mpa compressive strength were cast. To activate corrosion in

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specimen 12mm rebar were used. Standard steel of 500Mpa TMT rebar was used for reinforcing specimen along each side of length 600mm and 400 mm was used with the nominal top and bottom cover of 20mm.

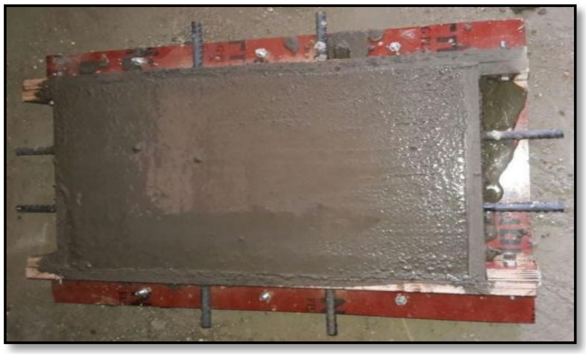

Figure No. 1 RC rectangular specimen.

Figure No 2 Moulde for casting of specimen

For casting of specimen, moulds were fabricated as shown in figure 2.Before casting, rebar are drilled with 4mm tap and threatened to facilitate the accommodation of copper screw for electrical connectivity as shown in figure 3. These rebars are cleaned with wire brush and washed with water so as to remove surface grim. Then the rebar was coated with standard epoxy resin on exposed surface of rebar so as to protect the rebar from corrosion activity. After epoxy coating rebar was well dried for 24 hours and then each bar was weighted with accuracy 0.01 g. RC specimen was cast in moulds and dried for 24 hours. This specimen was kept for curing for the period of 14 days at room temperature. On 15th day specimens are saturated in 5% NaCl solution to achieve the salinity of seawater at room temperature for 24 hours. After 24 hours i.e. on 16thday specimen was monitored with electrochemical techniques.

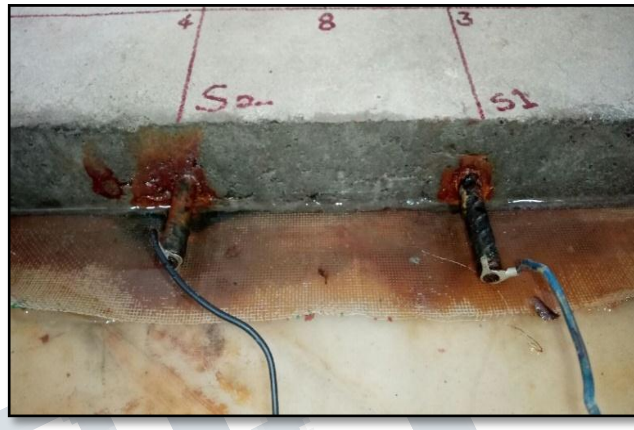

Figure No 3 Electrical connectivity for accelerating rebar

2.2. Accelerated corrosion technique

In present work impressed current technique was used to accelerate rebar in short time. This technique has the ability to control the rate of corrosion, which usually varies due to changes in the resistivity, oxygen concentration, and temperature. Any change in one of the variables would be compensated for. An accelerated corrosion test by the impressed current technique is confirmed to be a valid method to study the corrosion process of steel in concrete and its effects on the damage of concrete cover [2]. Set-ups used for inducing reinforcement corrosion through impressed current consist of a DC power source, a counter electrode, and an electrolyte. The positive terminal of the DC power source is connected to the steel bars (anode) and the negative terminal is connected to the counter electrode (cathode). The current is impressed from counter electrode to the rebar through concrete with the help of the electrolyte (i.e. 5% NaCl solution) as shown in figure no 4. The constant supply of 8V current is applied to the specimen for 10 days. When specimen show wide crack specimen is terminated and crushed to record the weight of corroded rebar.

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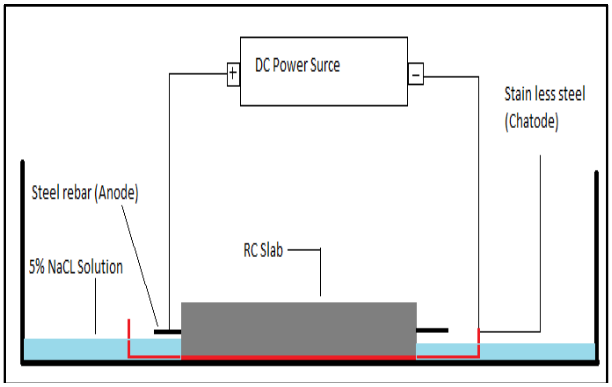

Figure No. 4 Schematic diagram for impressed current technique.

2.3. Monitoring of specimen

To collaborated relation between the qualitative and quantitative measurement of corrosion, Half-cell Potential and Corrosion current density technique were used. For Half-cell Potential measurement Saturated Calomel electrode is used as the reference electrode and Corrosion current density is determined by Tafel extrapolation method which is based on polarization technique. Potentiostat model 0.1 (Crest Technology) was used to obtain Tafel plot. Half-cell Potential values are recorded on the surface of the specimen at specific locations 1,2,3,4,5,6,7 and 8.Corrosion current density values are recorded at specific location 2,5,7 and 8 as shown in figure no 6.Specimens were monitored for 10 days till the wide surface crack occurs on the specimen. Periodic measurement of corrosion is worked out till specimen shows wide surface crack. In Tafel extrapolation method, a potential scan is applied to the specimen starting from Ecorr at the rate of 0.5 mV/s between the potential range of +250mV to -250mV in the cathodic or anodic direction. Before commencing specimen monitoring, current supply was terminated for two hours for the stability of iron flow in the specimen.

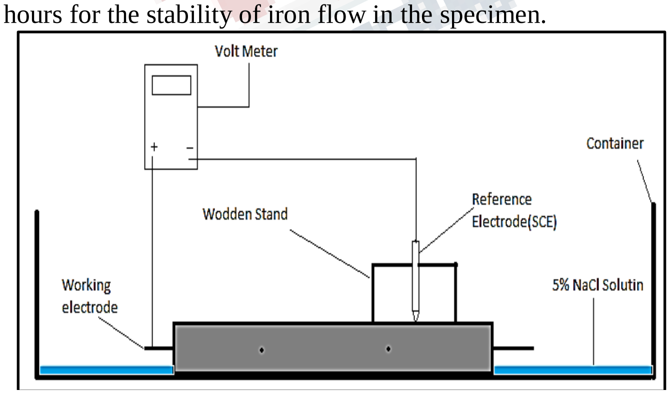

Figure no 5. Schematic diagram of monitoring specimen by Half Cell Potential.

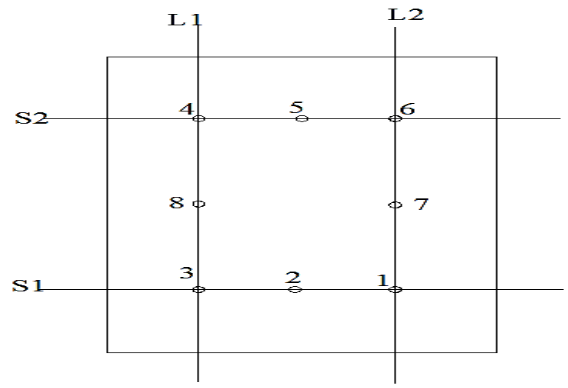

Figure No. 6 Location of readings.

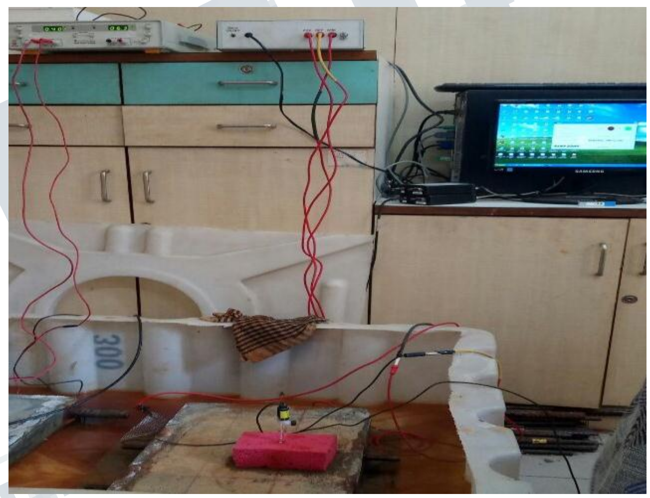

Figure no .7 Experimental set up

III. RESULTS AND DISCUSSION

2.4.1. Relation between Half Cell-potential and corrosion current density

From the experimental investigation, data interpretation is carried out by regression analysis. In view to establishing the relation between Half-cell potential and corrosion current density, the graph of corrosion current density values vs. average Half-cell potential values is plotted as shown in fig. 8. After experimental study and regression analysis of data, it is observed that the scatter in the plot is wide indicating poor co-relation between the two parameters which concludes that no mathematical relation can be established between Current Density and Half-cell. The reason for this is the variation of Icorr values with respect to time is not similar to that of Half-cell Potential values as shown in figure no 9 and figure no 10.

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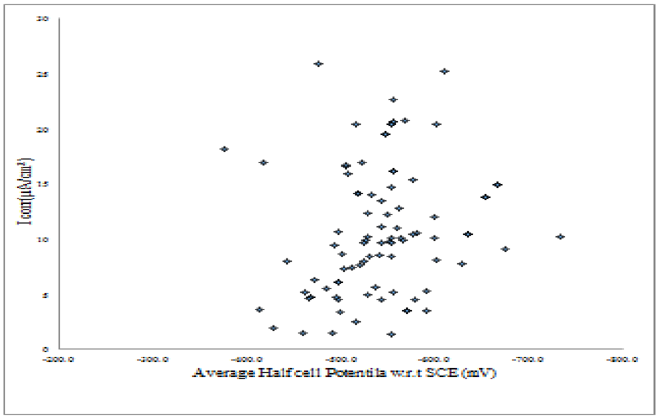

Figure No. 8 Relation between Half Cell-potential and corrosion Current Density

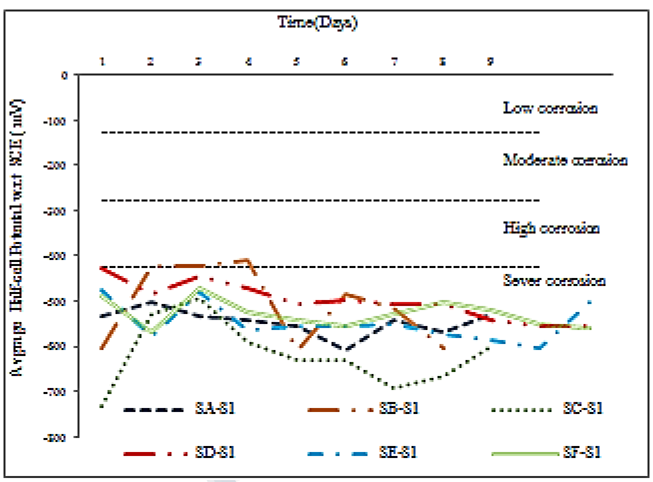

Figure no.9 Variation of Half Cell-potential with respect to time

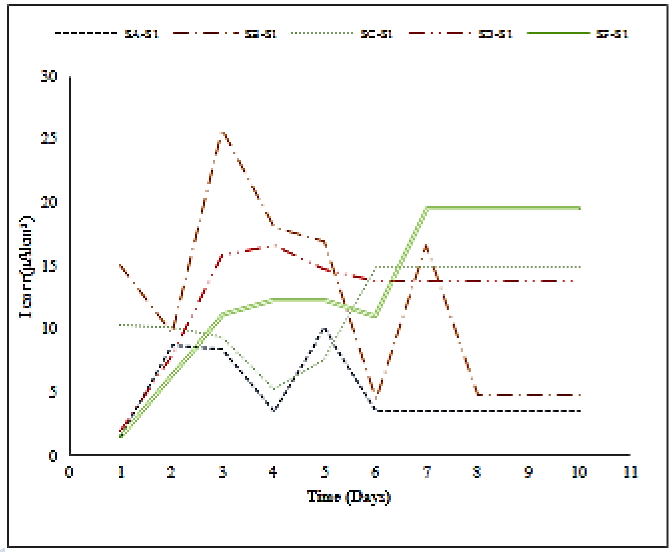

Figure no 10 Variation Corrosion Current Density with respect to time

IV. CONCLUSION

From the experimental work, it is observed that the results of Half-cell Potential measurement are exactly opposite to the corrosion current density values until the specimens show oozing of corrosion products on concrete surface. After oozing that is, when the rebar show the high level of corrosion the behavior of rebar identified by both the techniques is similar. This might have resulted in non-establishment of mathematical relation between two electrochemical technique used for corrosion assessment of rebar embedded in concrete.

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