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Effectiveness of Rebar Coatings against Corrosion

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Abstract: **Corrosion of steel rebar in reinforced concrete constructions, particularly those located in marine environments and industrially polluted areas is one of the major problems. Under such aggressive exposure a suitable method for protection of rebar from corrosion is necessary. Application of suitable protective coating on rebar surface is widely used practical method for this purpose. Such coating is ranged from cement slurry to epoxy. Varity of such coating are available in market leading to the difficulty of selection of appropriate coating depending on its performance. Therefore, the present work aims to study the behavior of different coating used to protect the rebar corrosion and its performance evaluation based on electrochemical measurement. For assessment of progress of corrosion, Half Cell Potential technique is used in the present work. From the experimental work it is observed that epoxy coating is more effective against corrosion.**

***Index Terms*— Coating, Corrosion, Half cell potential technique, Non-Distractive test, Rebar.**

I. INTRODUCTION

The Corrosion of steel in concrete construction, particularly those are located in industrial polluted area and marine environment is one of the major problems. Due to large calcium hydroxide fills in the concrete pores based on the hydration reaction of cement; the concrete pore solution keeps a strong alkaline medium. In this alkaline environment, a stable passive film forms on the surface of rebar, which provides a good protection to the steel rebar against corrosion [1]. However, because of the carbonation of concrete and/or ingress of chloride, the passive film of steel becomes unstable and the corrosion takes place. There is certain critical value for the pH and Cl concentration in concrete, above which the risk of corrosion is high [1]. To avoid the corrosion of steel, various methods are available like use of high quality of concrete, sufficient thickness of concrete cover; modifying the chemical composition of steel rebar and metallic and organic coating on surface of rebar [2]. Coatings on steel whose performance against chloride- induced corrosion are widely reported in literature include: zinc, tin, lead, nickel–phosphorus, mill-scaled, polished, brown rusted, black-rusted, polyaniline–nylon, silane, copper-clad and epoxy coatings [3]. However, these coating suffer from the major disadvantages that they may be physically damaged or electrochemically penetrated So that the base steel is vulnerable to pitting corrosion. Beside these limitations, use of such coating is widely followed for protection of steel embedded in concrete from corrosion. Hence present work aims to study the behavior of different types of coating used to protect the rebar corrosion.

A cheng et al[4], Studied that the effect of zinc-coating on corrosion resistance of rebar. The specimen exposed in 3.5% NaCl solution and direct current technique was applied. By using the open circuit they evaluate the rebar corrosion, they found that the corrosion rate of Zinc coating is higher than the carbon steel [4]. The study on corrosion performance of electro-less nickel–phosphorus (ENP) alloy coatings applied on steel rebars embedded in concrete subjected to chloride-induced corrosion, conducted by Singh and ghosh [3], has indicated a high degree of protection against corrosion of ENP alloy coatings. Researcher studied the corrosion behavior of epoxy/zinc duplex coated scratch rebar embedded in concrete was evaluated and comparing with the black steel, galvanized and epoxy coated rebar[1]. After some day they found corrosion occurred at scratched portion in epoxy coated rebar.

From literature review it is observed that, to study the effective of different coatings against corrosion the researchers developed either scratch on coating surface or certain portion of steel kept uncoated. But practically fully coated reinforcing bars are placed in RC structures. Hence evaluation of corrosion in such bars using electrochemical technique, because difficult as instruments used required direct contact with steel surface. In such situation it is necessary to check the applicability of electrochemical technique for corrosion evaluation of coated bars. Hence the aim of present work is to study the behavior of different coatings used to protect the rebar corrosion and to develop the suitable methodology for checking the performance of the coated rebar under corrosion.

II. EXPERIMENTAL PROGRAM

A. Material

Concrete mix of 35 grade made with, Ordinary Portland cement of 53 grade, and maximum aggregate size of 10 mm were used in this experiment. Natural river sand was used as fine aggregate. The concrete mix was designed as per IS-10262:2009. The mix proportion used was with water-cement ratio of 0.5. The compressive strength of concrete after 7 Days and 28 Days was 25.6 mPa and 36 mPa respectively. Fe 500 grade of TMT rebar having 16 mm diameter was used in this experiment. Two different types coating material named epoxy resin and primer paint was used to coat the rebar.

B. Preparation of specimen

For the experimental study, concrete cylindrical specimen of embedded steel bar at centre were used. The dimension of cylinder was 60 mm diameter and 100 mm height. The reinforcing bar of 110 mm length and 16 mm diameter was embedded at the centre of specimen with 20 mm clear cover. Before casting, 4 mm diameter groove was drilled at one end of rebar for the purpose of connecting the conducting wire for electrochemical measurement. Then by using wire brush the surface of steel rebar was cleaned. One specimen were coated with epoxy, one with primer allowed 24 hour for harden. Before casting the cylindrical specimen, weight of every rebar was measured with accuracy of 0.001 gm. For the purpose of casting cylindrical specimen, the special stand was prepared and shown in fig 1. All cylindrical specimens cured for 7 days period after demolding. After finishing curing specimen was immersed in 5% NaCl solution for the saturation purpose. From next day the impressed current technique was applied for acceleration.

Figure 1 Special Molding systems used for Casting of Specimen.

C. Accelerated corrosion set up:

Natural corrosion process is a very slow process. In order to study the corrosion in coated rebar, this time will further increase. Hence among these impressed current technique found more effective from literature. The commonly used methods of inducing corrosion in RC specimen are salt spray, chloride diffusion, alternate drying and wetting in salt water, impressing anodic current[5]. completion of experimental work in the time acceleration of corrosion was done using impressed current technique. The corrosion process accelerated by impressing a positive direct current into the reinforcing steel bar to act as anode and negative current into some external inert cathode, using external DC source thereby developing a corrosion cell. The corrosion induced by this procedure is similar to the corrosion induced under natural conditions. In present Experiment work the stainless steel mesh was used as a cathode and steel rebar as anode. The RC specimen and steel mesh is immersed in 5% NaCl Solution. The reinforced steel rebar was connected to the positive terminal of the DC power supply by using conducting wire. The steel mesh was connected in the form series to the negative terminal of DC power supply. The constant voltage of 10 V was applied in between anode and cathode. Every day the impressed current paused for half hour and potential of steel rebar imbedded in concrete was measured using Half-cell potential. The accelerated corrosion process stopped when concrete specimen, showed crack on its surface. The accelerated corrosion setup shown in the fig. 2

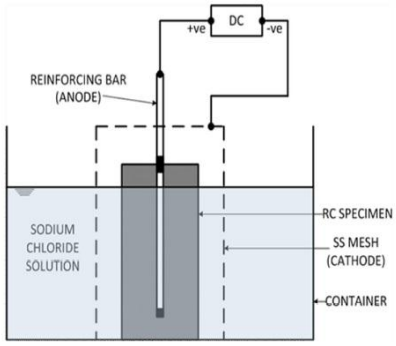

Figure 2. Schematic Representation of Experimental Set-up for accelerated corrosion [6]

D. Evaluation of corrosion

Corrosion is electrochemical process; therefore the assessment of progress of corrosion is carried out by various electrochemical tests like half cell potential, linear polarization resistance (LPR) method, AC impedance spectroscopy etc. In amongst all these the half cell potential is used commonly.

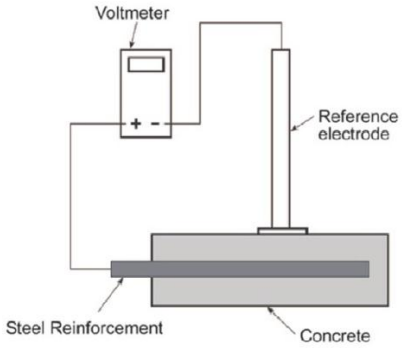

Figure 3 Principle and Components of Half-Cell Potential Measurements

In this investigation the half cell potential technique was used for measurement of corrosion activity. The method of half-cell potential measurements normally involves measuring the potential of an embedded reinforcing bar relative to a reference half-cell placed on the concrete surface [7]. There are two basic types of half-cell is used named as copper/copper sulphate or silver/silver chloride cell. In Table.I Half cell potential values for different reference electrodes are shown. The concrete functions as an electrolyte and the risk of corrosion of the reinforcement in the immediate region of the test location may be related empirically to the measured potential difference[7] ASTM C876 - 91 gives a Standard Test Method for half-cell potentials of uncoated reinforcing steel in concrete. Measurements are made in either a grid or random pattern. As shown in Fig.3 direct electrical connection is made to the reinforcing steel with a compression clamp or by brazing or welding a protruding rod.

Table. I corrosion condition related with half-cell potential (hcp) measurements [7]

Open circuit potential (OCP) values		Corrosion condition
(mV vs. SCE)	(mV vs. CSE)	
< -426	< -500	Severe corrosion
< -276	< -350	High (<90% risk of corrosion)
-126 to -275	-350 to -200	Intermediate corrosion risk
> -125	> -200	Low(10% risk of corrosion

III. RESULTS AND DISCUSSION

A. Half-cell potential

During the progress of Corrosion, variation in half cell potential was observed for epoxy and primer coated rebar as shown in figure 4 and figure 5 respectively.

From figure 4 it is observed that the half cell potential values for epoxy coated rebar found most of the time less than -0.126 V which indicate low risk of corrosion. The total period for testing of epoxy coated rebar specimen was one month, in which the specimen showed very low risk of corrosion even subjecting to accelerated corrosion using impressed current technique. on the other for specimen with primer coated rebar half cell potential varied between -0.119 V to -0.565 V during 15 days of test period. When the potential value reach upto -0.445 V, crack was observed on surface of RC specimen. thus specimen with primer coated rebar, the risk of corrosion was observed higher than 90% during test period.

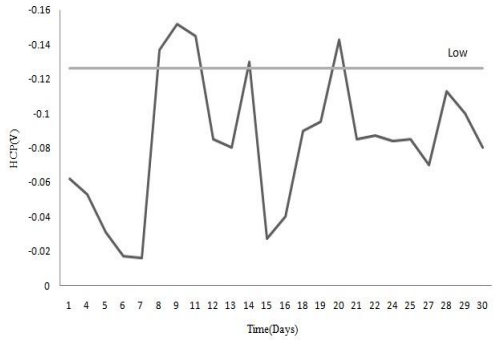

Figure 4 HCP verses Time plot for Epoxy coated rebar.

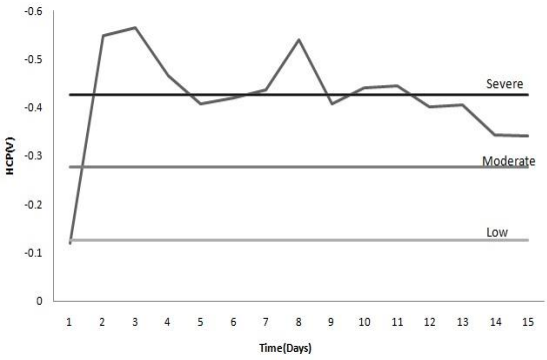

Figure 5 HCP verses Time plot for Primer coated rebar.

B. Mass loss

After completion of test, specimen were broken and mass loss of rebar was measured to calculate percentage mass loss in each specimen. Table No. II gives the percentage mass loss values for both specimens from the table it was observed that, the primer coated rebar shown 10 % mass loss after completion of test. Whereas epoxy coated rebar shown no mass loss at all.

Table. II Mass loss of coated rebar

Sr No.	Type of coated rebar.	Weight of rebar before corrosion (gm)	Weight of rebar before corrosion (gm)	Percentage mass loss
1.	Epoxy	95	95	0.0
2.	Primer	172.5	155	10.14

C. Visual Inspection

The following points were observed by visual observation:

- On the surface of concrete specimen with epoxy coated rebar, no corrosion products were found. Whereas in case of primer coated rebar specimen, brown stains were observed at approximately 9th day of testing.
- Hair line crack was observed on the surface of concrete specimen with primer coated rebar while specimen with epoxy coated rebar has shown no crack at all.

IV. CONCLUSION

Based on the experimental study, the following conclusions are drawn:

- From the visual inspection, the presence of corrosion products on rebar coated with epoxy found to be very low as compare to rebar coated with primer
- From the study of mass loss, rebar coated with epoxy resin shown lesser mass loss as compared to that of primer coated rebar indicating significant resistance against corrosion.
- Based on variation of half cell potential values it can be concluded that, half cell potential technique can be used for monitoring corrosion of fully coated rebar. In present study, half cell potential measurements indicated that epoxy coated rebar are more effective in corrosion resistance as compared with primer coated rebar.
- Thus, it can be concluded that the epoxy coating to rebar is more effective against corrosion resistance as compared to that of primer coated rebar.

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