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Corrosion Assessment in Reinforced Concrete Elements using Half-Cell Potentiometer – A Review

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Abstract:
The early failure of structure is due to the corrosion of reinforcement steel bars which leads to decrease in serviceability and durability of the structures then causing structural properties of structural elements [1,2]. Although the reinforcing steel bar is covered with concrete in passive film like form to enhance high alkalinity, if pH is enormously decreased the protecting film is damaged. To avoid the failure, forecasting of corrosion rate is to be done to reduce the maintenance cost. To this end, non-destructive evaluation methods are to estimate the corrosion rate on reinforcement bar. There are few non-destructive methods instruments are commercially available in markets. A brief comparative study has been performed and presented in this review paper using half-cell potentiometer.

1. INTRODUCTION

The chloride attack on the reinforcing steel bars which leads to corrosion causing premature failures and damages of structural elements takes place. If concrete covers contains chloride concentration in higher level, result in loss of strength, fatigue, reduced bond strength, limited ductility on RC [reinforced concrete] structures. This state of affairs represents a excessive corrosion threat in systems; corrosion attack turns into viable in the presence of oxygen and humidity on the metal. Chloride-triggered corrosion of steel in concrete is as a minimum on the start. With the improvement of lively and passive macro-cells[2]. The corrosion of reinforcement increases the volume of reinforcement from its actual volume which leads to spalling of structural elements.The half-cell potentiometer estimation is utilized to find the nearness of consumption rate on reinforcement bars. The most important objective of this paper is to enable the engineers to higher interpret the outcomes of half-cell potential measurements. The results of the measurement relates the potential readings on the reinforced concrete gives corrosion rate in localized reinforcement corrosion via concrete resistivity and temperature, enables the engineers to comparing supplementary records from half-cell potentiometer tests. This review projects the half-cell potentiometer readings obtained from various corrosion affected areas[5–7]. The one of the best strategy to decide the corrosion rate is half-cell potentiometer.However non-destructive tests should be provided to support corrosion measurement [9–12].

2. HALF-CELL POTENTIOMETER ON REINFORCED CONCRETE ELEMENTS

The half-cell potentiometer instrument is used in reinforced concrete elements to estimate the corrosion rate on cylindrical specimen in actual and corrosion induced condition. The reference electrode of copper-sulphate solution with copper strip which is placed on the concrete surface and the other electrode is clipped in reinforcing bars to measure the difference in potential and electrical difference between the reinforcement and concrete to calculate the corrosion rate of reinforcement steel bar of the specimen. The electrical activity of the steel reinforcement and the concrete to be considered the steel as one electrode and the concrete as the electrolyte. The potential variation between the electrodes is measured and notted as Ecorr. The numerical values of the measured corrosion rate depends on the nature of material used as a reinforcement and the reference electrode used was suggested by Lukasz Sadowski[9]. He also suggested that the concrete cover over the reinforcement also plays an effect over the potential

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difference in corrosion measurement, the potentials are thus influenced by using resistance drop inside the cover, through macro-cell current and possibly through junction potentials. It isn't always necessary to install half-cells on all over a structure to display its changing corrosion situation [7] suggested by John P. Broomfield. Be that as it may, the consumption rate decided utilizing half-cell potentiometer is fit in assessment of in-situ properties (erosion rate) and utilized in innovative work. This strategy is reasonable for different auxiliary individuals in changing size of profundity of solid spread over reinforcement steel bar and it might utilized whenever during the existence a solid part. The results determined by half-cell potentiometer gives the rate of corrosion in reinforcement bars embedded in concrete as mentioned by ASTM. The resistance offered by concrete to the passage of electricity is measured using half-cell potentiometer. It consists of pre-wetted sponges which is contact with low electrical resistance in solution. The tip of half-cell is attached with sponge to from electrical continuity between the surface of concrete specimen and porous plug in it. The half-cell potentiometer is used to evaluate the corrosion rate of reinforcement bars in order to control the expenses on maintenance of the structure. This method is also implementable in existing structures in embedded and non-embedded form of test.

3. NEED OF SEWAGE TREATMENT PLANT [STP] WATER

In earth, 3% of fresh water is available in order to avoid excessive usage of fresh water, replacement of STP water over fresh water in varied proportion is studied in this project on various mechanical properties and also its influence in corrosion rate.Water is the major component in concrete which acts as lubricant in the mixture of cement and aggregates to bind. Sewage treatment is the process of eliminating the contaminants from waste water. It includes physical, chemical, and biological processes of removing the contaminants. In this project, STP water is replaced over fresh water in varied proportions to determine influence of STP water in the strength of concrete and corrosion rate of reinforcement steel bar. The STP water is collected from our institutional palnt. STP water is used in specimen casting in varied proportions in order to check the corrosion induce on reinforcement bars in specimen.

4. TESTS CONDUCTED

4.1. Compressive strength test

To determine the average compressive strength of concrete, 150mm cubes were used having 1:1.8:2.9 mix with 0.5 water-cement ratio.Specimens with normal water replaced by STP treated water at 0%, 25%, 50%, 75%, and 100% were casted. During moulding, the cubes were manually damped. After 24hour of setting, the specimen are marked and removed from the moulds and are immediately submerged into clean, fresh water. The specimens allowed for curing is taken after 7, 14, and 28 days. The compression tests on cube specimens are tested on three cube specimens in each proportion of replacement of water. The load is applied without continuously until the specimens get break down. The average values of compression strength is recorded.

4.2. Split tensile test

Concrete cylinders having 150mm diameter and height twice of it can be used to obtain the split tensile strength. The concrete mix was designed as 1:1.85:2.9 with 0.5 water cement ratio. Specimens with ordinary portable water replaced by STP treated water at 0%, 25%, 50%, 75%, and 100% replacement levels were cast. After 24 hours of initial setting of concrete, the specimen is removed from its moulds and allowed to curing for 7, 14, and 24 days. Compression testing machine is used for testing by placing jigs on plane of loading in parallel position centrally on the lateral sides of cylindrical specimens to be tested.The average split tensile strength of concrete can be obtained by testing the available five specimens.

5. CORROSION INDUCING TECHNIQUE

5.1 Impressed Current Technique

Corrosion is induced in steel using impressed current technique comprises of DC power source supplied to anode and cathode. Here, the DC power source with positive terminal is clipped to reinforcement bar of the specimen and the negative terminal is connected to the reference electrode of steel, then this set-up is dipped into 5%

NaCl solution with 0.03N along with specimen about 3/4th of the specimen to induce corrosion in the reinforcement bar for short period of time in normal environmental condition. The rate of corrosion on reinforcement bar is calculated theoretically by the difference in the normal and corrosion induced specimens [14].

5.1.1 The experimentalset-up for corrosion induction of concrete

For experimental purposes, corrosion is to be induced with the help of impressed current technique. This method uses NaCl as the electrolyte and steel reference electrode and the direct-current power source. The DC power source is connected to reinforcement bar which acts as an anode and to the reference electrode which acts as a cathode which is immersed in the NaCl electrolyte (5% of sodium chloride with 0.03N) to induce corrosion on reinforcement in specific interval of time (1 hour). To induce the corrosion in reinforced concrete cylindrical element by impressed current technique with this experimental set-up [1].

6. HALF-CELL POTENTIOMETER TEST SETUP

After 28 days, corrosion rate is measured in concrete and found that the potentials reaches negative values in wet situation and in dry conditions the values reaches up to 350mV. The half-cell potentiometer is consist of voltmeter, reference electrode and true electrode. Potential difference is measured with the help of voltmeter which reinforcement bars and a reference electrode placed over the concrete. The varied values of potential gives the rate of corrosion in reinforcement bar. The reference electrode is of copper strip and copper sulphate solution with copper crystals. The potential measurement is referred in the below given table to obtain rate of corrosion in reinforcement bars. The test setup used my Manzur, et al., is given in Fig.1

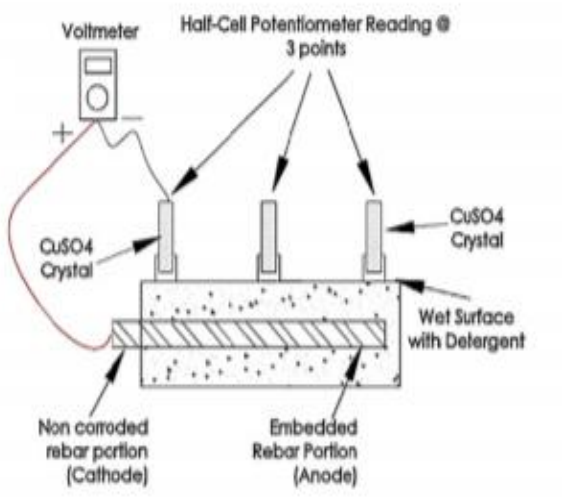

Fig.1. a) Schematic diagram for corrosion measurement

Fig.1. b) Experimental set up corrosion measurement

Contour maps were plotted against the corrosion rate and time. Potential gradient obtained gives the rate of corrosion occurred in reinforcement bars.. The test results can be interpreted based on the following table.

Table 1. Corrosion rate measurement

Potential Difference(mV)	Corrosion Rate(%)
>-200	<10
-200 to -350	uncertain
<-350	>90

6. CONCLUSION

This review paper gives the information about the effect of corrosion on the strength of the concrete which can be obtained by the application

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of half cell potentiometer technique. The half-cell potentiometer techniques for determining reinforcement corrosion rate. This method gives effective results in both insitu and exsitu conditions in structures.

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