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Study on the Corrosion Rate of Rebars Embedded In Concrete Mixes of Various Grades

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Abstract: ***Corrosion is a natural process, which converts a refined metal to a more chemically-stable form, such as its oxide, hydroxide, or sulphide. Corrosion initiation takes place when the chloride concentration at the rebar level reaches a critical value. The critical chloride level to develop active corrosion of the steel reinforcement is not a unique value. The main reason for the ambiguity and uncertainty about this critical chloride level, which is also often referred as threshold chloride concentration, is its dependency on large number of variables. This study is intended to study the corrosion rate of steel reinforcement embedded in Ultra High Strength Concrete (M100), Ultra high strength concrete(M100) with water soluble polymer and Medium Strength Concrete(M30). The result shows that the M100 grade concrete shows lower corrosion rate than normal strength concrete. The M100 concrete with water soluble polymer exhibits very high rate of corrosion rate.***

Keywords: ***Polymer Concrete, Ultra High Strength Concrete, Medium Strength Concrete, Silica Fume, Quarry Dust and Corrosion rate***

I. INTRODUCTION

A. General

Corrosion initiation takes place when the chloride concentration at the rebar level reaches a critical value. The critical chloride level to develop active corrosion of the steel reinforcement is not a unique value. The main reason for the ambiguity and uncertainty about this critical chloride level, which is also often referred as threshold chloride concentration, is its dependency on large number of variables.

The determining parameter indicating corrosion initiation shall account for steel surface condition and/ or steel type in addition to accounting for the concrete characteristics and chloride ion concentration. Thus pure chemical indicators such as critical levels of free chloride, total chloride or [Cl-/OH-] ratio may not be adequate for indication of rebar corrosion initiation against chloride induced corrosion. Electrochemical indicators on the other hand may account for both steel as well electrolytic condition of concrete. The values of corrosion current density, a determining parameter for indication of corrosion initiation obtained by different techniques vary from each other. In addition the corrosion rates obtained by different corrosion monitoring equipment’s also do not agree with each other. On the other hand half-cell potential value is measured with reference to a standard reference electrode, and depends on the steel type and the electrolytic environment of concrete surrounding it.

The method of measurement is based on a simple technique and well established equivalence is available for converting the potential obtained from one reference electrode to another. Thus half-cell potential can serve as a determining parameter for indicating initiation of corrosion. For this purpose in this chapter an attempt has been made to experimentally demonstrate the suitability of half-cell potential as a determining parameter for indicating rebar corrosion initiation and to study the effect of different types of admixtures used in concrete.

B. Concrete corrosion

Corrosion is a natural process, which converts a refined metal to a more chemically-stable form, such as its oxide, hydroxide, or sulfide. It is the gradual destruction of materials (usually metals) by chemical and/or electrochemical reaction with their environment. Corrosion engineering is the field dedicated to controlling and stopping corrosion.

In the most common use of the word, this means electrochemical oxidation of metal in reaction with an oxidant such as oxygen or sulfur. Rusting, the formation of iron oxides, is a well-known example of electrochemical corrosion. This type of damage typically produces oxide(s) or salt(s) of the original metal, and results in a distinctive orange colouration. Corrosion can also occur in materials other than metals, such as ceramics or polymers, although in this context, the term "degradation" is more common.

Corrosion degrades the useful properties of materials and structures including strength, appearance and permeability to liquids and gases.

C. Need for corrosion analysis

The advantage of evaluating the performance of rebar against corrosion in concrete made with internal chloride is to ensure the depassivation of the rebar right from the beginning as it comes in contact with the aggressive chloride-rich medium right from the moment of casting before the formation of an effective passive film.

The behaviour of rebar in concrete against internal chloride and external chloride exposures could be different. However the performance of rebar against exposure is important when concrete is prepared with chloride contaminated ingredients including chloride bearing admixtures. As stated earlier, the corrosion performance of steel reinforcement embedded in concrete exposed to environment depends upon the characteristics of both steel and concrete. A suitable combination of the steel and cement type can improve durability of the reinforced concrete structures. When information regarding the performance of RC structures against rebar corrosion has to be obtained within a restricted time, the application of various electrochemical techniques becomes important. Non-destructive monitoring of corrosion performance by different electrochemical tests has now become an important aspect of durability studies in concrete.

D. Scope of present study

A review of the literature reveals that the subject of corrosion is extremely complex and has received much attention resulting in a great many published studies. When the field is narrowed to corrosion of reinforcement in concrete, the number of publications is still relatively large. However, when one restricts his interest to corrosion stdies of specimens specifically designed to simulate real elements of highway structures, the number of available publications becomes quite small and none specifically involving Texas aggregates and mix designs are available.

II. EXPERIMENTAL INVESTIGATION

The experiment is being investigated by using same brand steel bars embedded in three concrete mixes namely polymer concrete, concrete grade of M100 and M30.

In M100 concrete mix the admixtures are added to achieve the strength. The admixtures used in the mix are Silica Fume and Superplasticizer. Silica fume is replaced by 6% by the weight of the cement and the Superpalsticizer is replaced by 2% by the weight of cement and Quarry Dust is replaced partially. The water content used for this mix 0.26.

For the M30 mix, it is as same as the nominal mix. The only similarities to both the mixes are replacing the Quarry Dust. Water content used in the M30 mix is 0.45. The other mix which is used in the project is M100 induced with Polymer.

Two sets of concrete cubes are casted for the experiment. In one set of cubes it is casted using different bars of different composition while another set of the cubes are casted with bars of same composition. The bars are cut in to a length of 360 mm for the purpose of placing the bars in the cubes.

The materials of required quantities are measured and taken as per the design mix and mixed thoroughly in the mixing pan. The concrete is then placed in the cube and compacted using vibrator and then the bars are then placed in the centre of the cube. And then the moulds are demoulded after 24 hours of casting, after that it is placed for curing. The mix designs are done by using ACI 211.1 – 91 and IS 10262:1982 respectively for M100 and M30 concretes. The mix proportion of M100 concrete and M30 concrete are shown in table 1 and 2.

Table 1. Mix Proportion of M100 Concrete

Quarry dust replacement %	Cement (kg)	Sand (kg)	Quarry dust(kg)	Silica fume(kg)	Coarse aggregate(kg)	Water (kg)	Super plasticizer(kg)
0	820	608	0	71.3	1108	214	17.8
10	820	547	61	71.3	1108	214	17.8
20	820	486	122	71.3	1108	214	17.8
30	820	426	182	71.3	1108	214	17.8
40	820	364	243	71.3	1108	214	17.8
50	820	304	304	71.3	1108	214	17.8
60	820	243	364	71.3	1108	214	17.8

70	820	182	426	71.3	1108	214	17.8
80	820	122	486	71.3	1108	214	17.8
90	820	61	547	71.3	1108	214	17.8
100	820	0	608	71.3	1108	214	17.8

Table 2. Mix Proportion of M30 Concrete

Quarry dust replacement %	Cement (kg)	Sand (kg)	Quarry dust(kg)	Coarse aggregate(kg)	Water (kg)
0	511	664	0	1108	230
10	511	598	66	1108	230
20	511	531	133	1108	230
30	511	465	199	1108	230
40	511	398	266	1108	230
50	511	332	332	1108	230
60	511	266	398	1108	230
70	511	199	465	1108	230
80	511	133	531	1108	230
90	511	66	598	1108	230
100	511	0	664	1108	230

A. Corrosion measurement

1) The instrument used for the test is GILL AC SERIAL NO 1829.
2) The connections from the instrument to the computer are to be done and the necessary software has to be installed.
3) Then for conducting the test NaCl solution has to be prepared by mixing 3% of salt to the quantity of water and the surface of the exposed bars are cleaned with emery sheet to necessitate the conductivity of the system.
4) After that the cube is immersed in the NaCl solution in such a way that the cube surface should be completely immersed in the solution.
5) Connection of the electrodes must be done. There are two electrodes used in this namely, Calomel Electrode which is used as Reference Electrode (RE) and Platinum Electrode is used as Axillary Electrode (AE). Then the working electrode is After the connections are made the connections are checked by "Rest Potential". The difference in values should not be
6) Then the "Gill AC Serial No 1829 Sequencer" is opened and the required operations are sequenced.
7) First the area of the specimen and the destination where the file is to be saved is entered.
8) In this work only two processes are used, first the "Current & voltage/time" is set up by entering the reading per test and cell settle time
9) The second process is "Long Term – LPR Sweep" and it is set up by changing the values of sweep rate and cell settle time.After finishing all the setup it is checked once again and the analysis is started by clicking "Run Now" on the right of the sequencer.
10) After clicking Run Now, the Core Running opens and the process will start as it is listed in the sequencer
11) Once all the processes are finished the values has to be analysed.
12) The "Analyser" is opened to take the values.
13) After opening the analyser the desired data is selected and for the selected data the graphs appear.Then the corresponding graph of "Long Term LPR – sweep" is selected and the graph is opened by clicking "GRAPH" which is placed in the top left corner of the analyser.
14) The selected graph opens in an enlarged view and the type of graph is changed to "Tafel" graph.
15) After the tafel graph opens the tangents to the curve are fixed by using "Tafel Rulers"s) The values are stored by clicking the auto button and to take the values the "Data Bank" is opened.
16) In the data bank the required values are taken.
17) The process for the required number of specimens and cycles.

The relevant photograph of the specimens and test setup are shown in figure 1.

a). Specimen

b). Test setup

c).Calomel electrode and Platinum electrode

Fig.1. Specimen and Test setup for Corrosion rate Analysis

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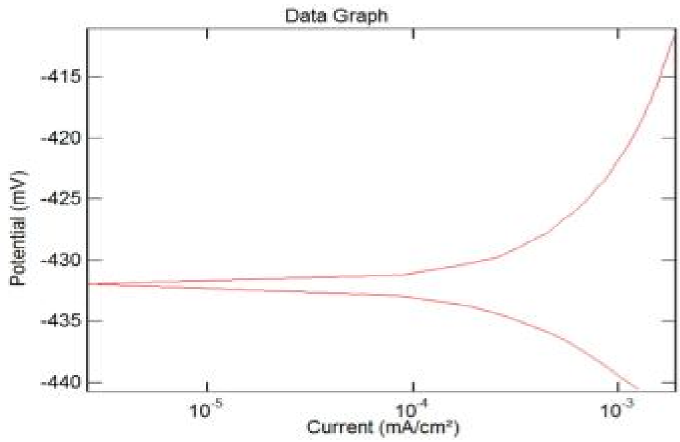
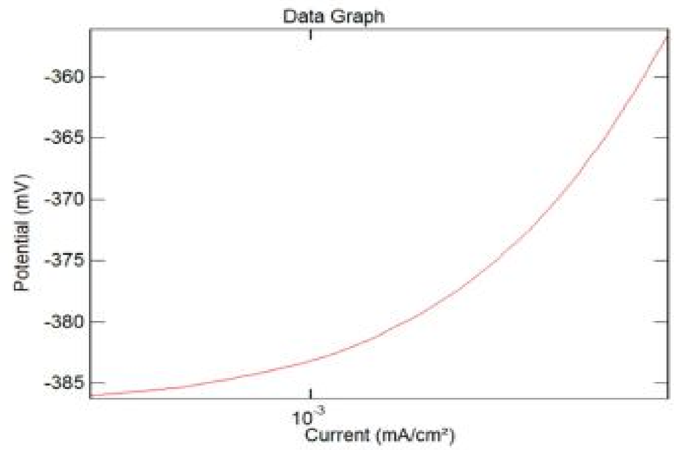
III.RESULTS AND DISCUSSION

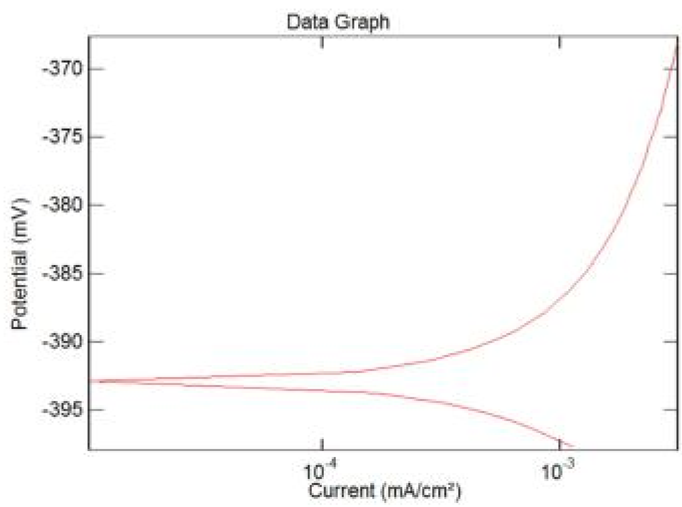
The corrosion test was conducted on M30,M100 and M100 induced with polymer concrete at 28 days with varying percentage replacement of quarry sand with embedded steel bars and TAFEL graphs are shown in fig.2,3 and 4.



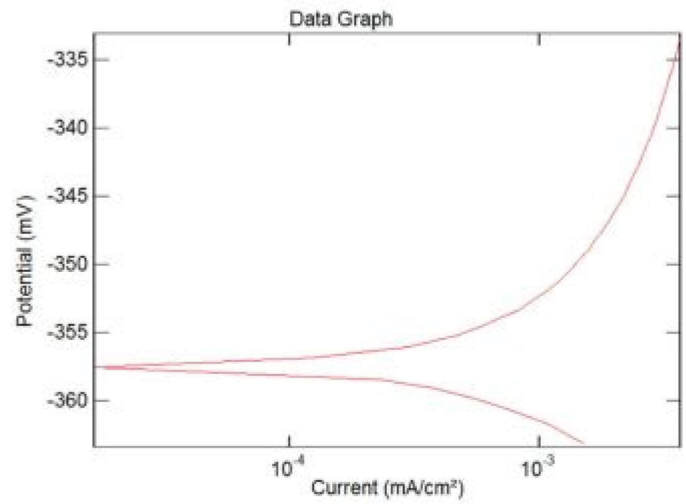
0 % Replacement of Quarry dust



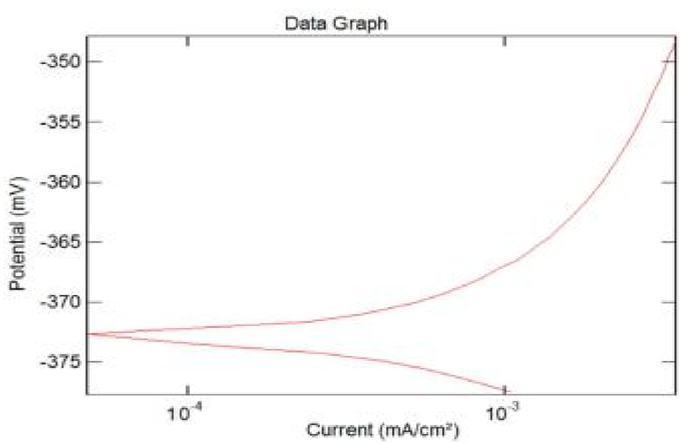
20% Replacement of Quarry dust



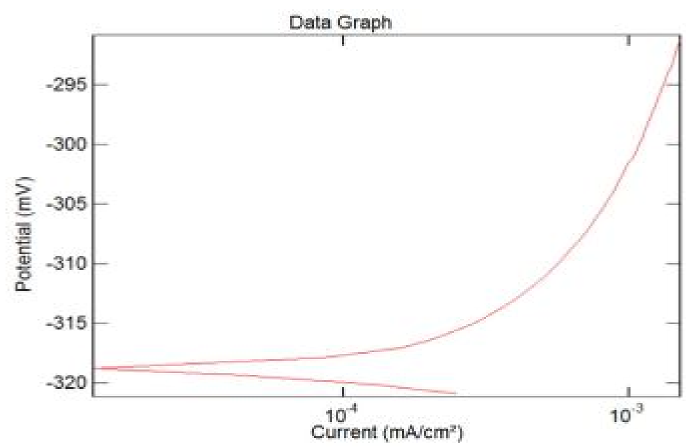
40 % Replacement of Quarry dust



60 % Replacement of Quarry dust

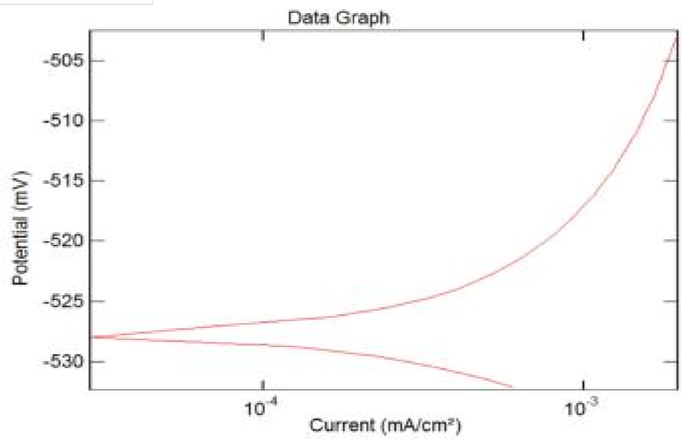


80 % Replacement of Quarry dust

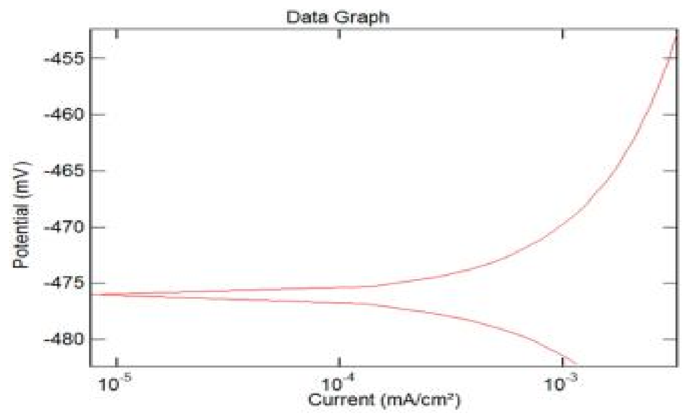


100 % Replacement of Quarry dust

Figure 2. TAFEL Graph M30 Concrete



0 % Replacement of Quarry dust



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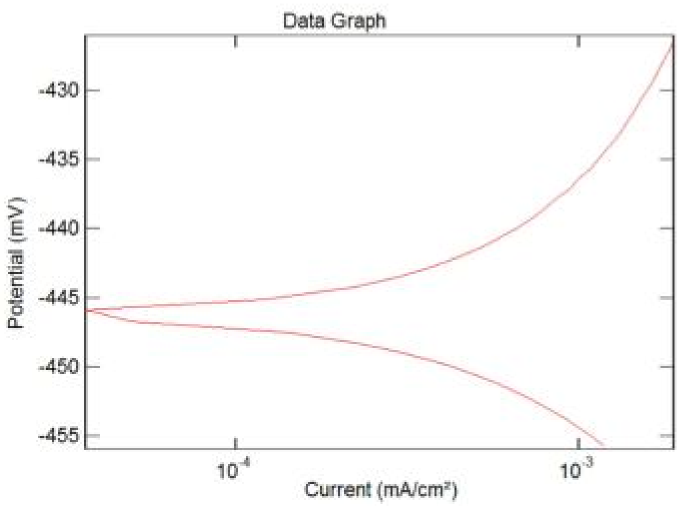

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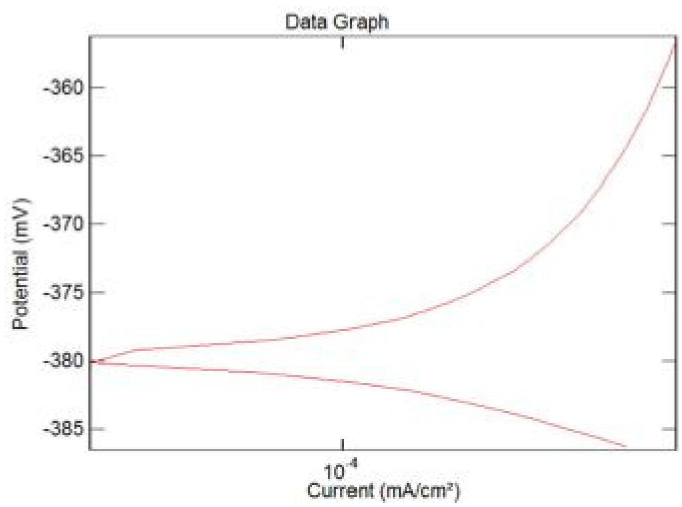

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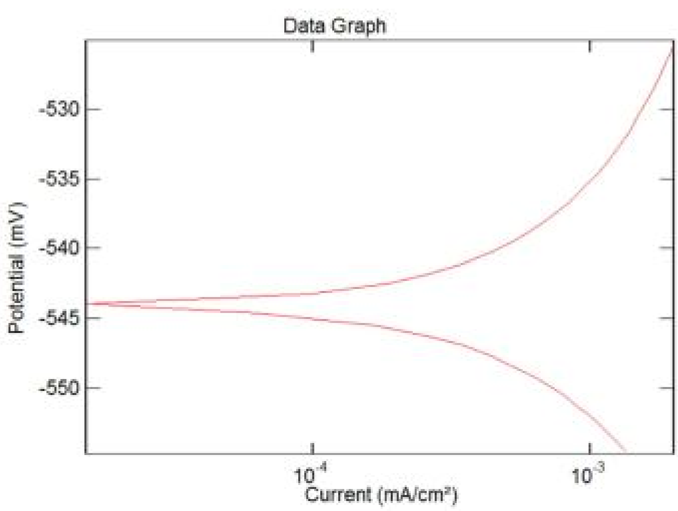
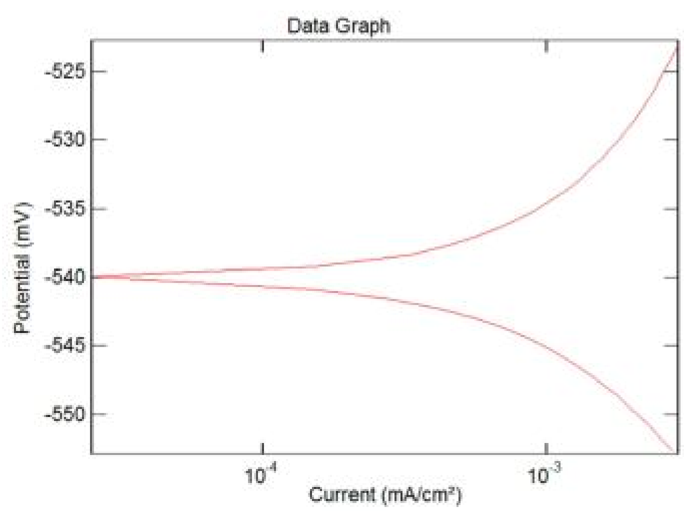


80 % Replacement of Quarry dust



100 % Replacement of Quarry dust

Fig.3. TAFEL Graph - M100 Concrete

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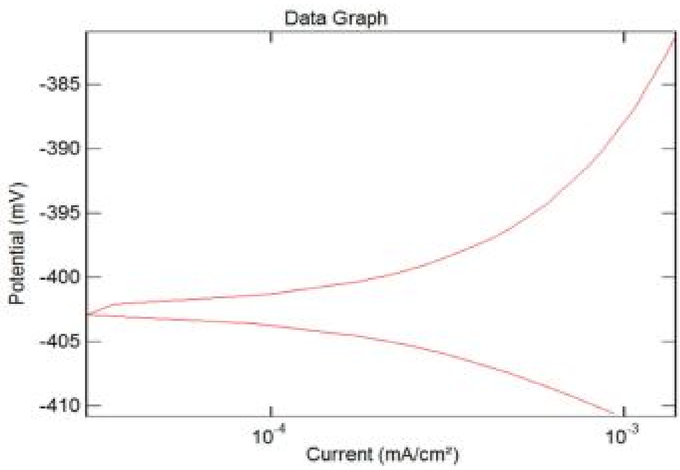
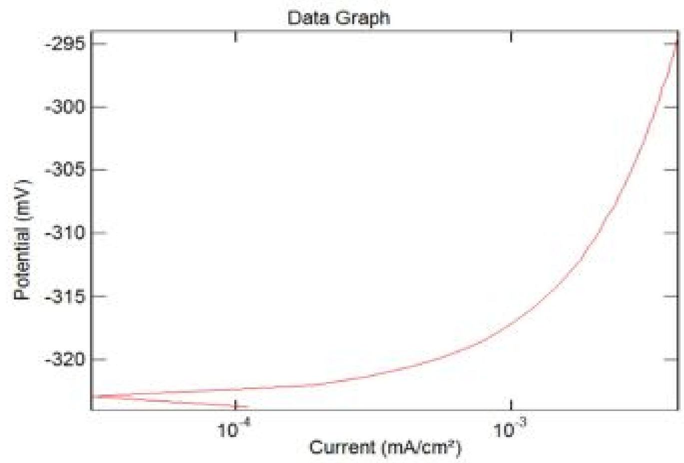
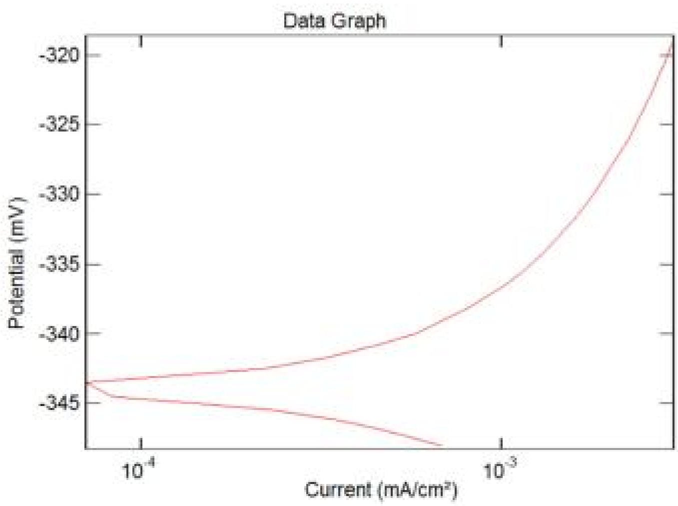
Volume 5 Issue X, October 2017- Available at www.ijraset.com



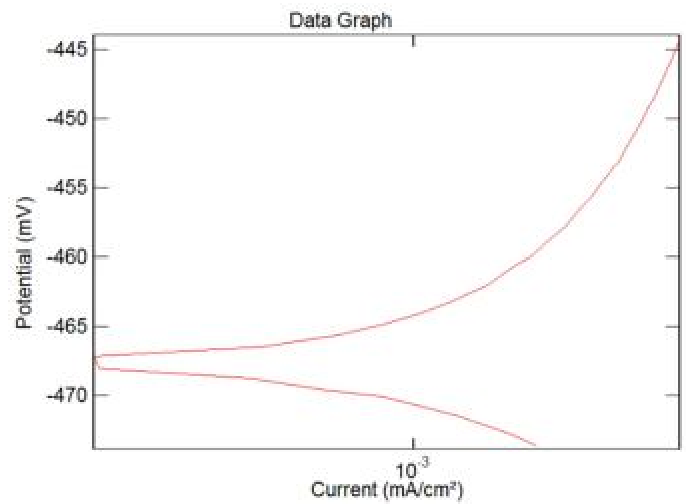
0 % Replacement of Quarry dust



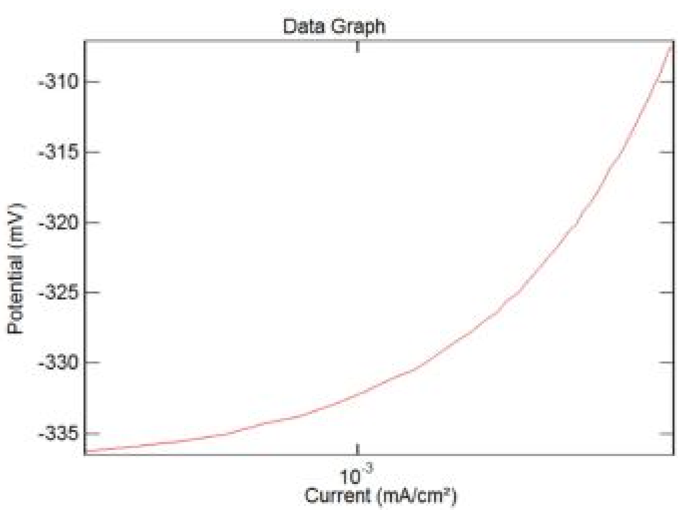
20 % Replacement of Quarry dust



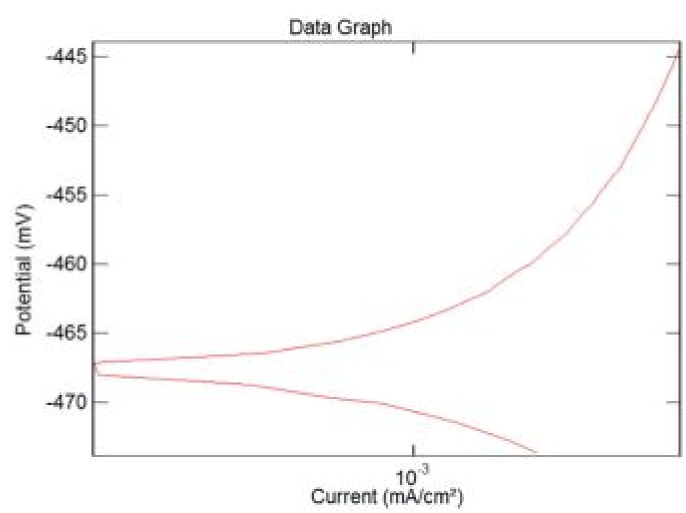
40 % Replacement of Quarry dust



60 % Replacement of Quarry dust



80 % Replacement of Quarry dust



1000 % Replacement of Quarry dust

Fig.4. M100 partially replaced with quarry dust and induced with polymer

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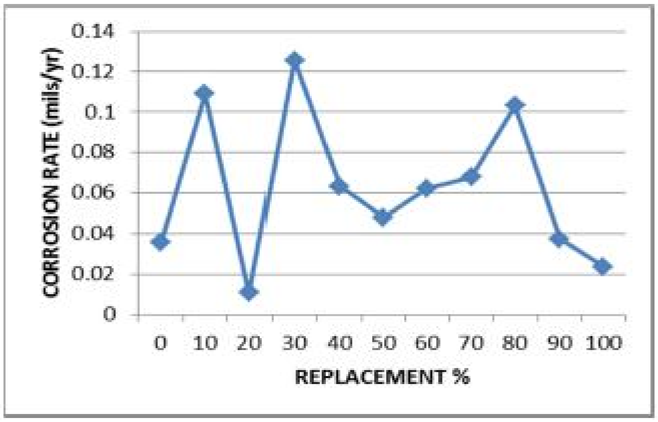
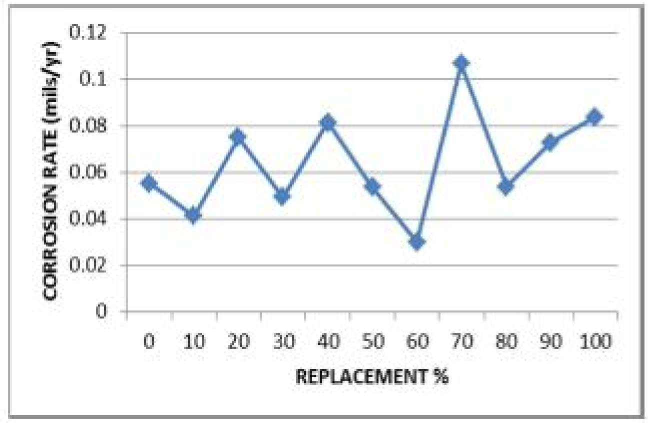
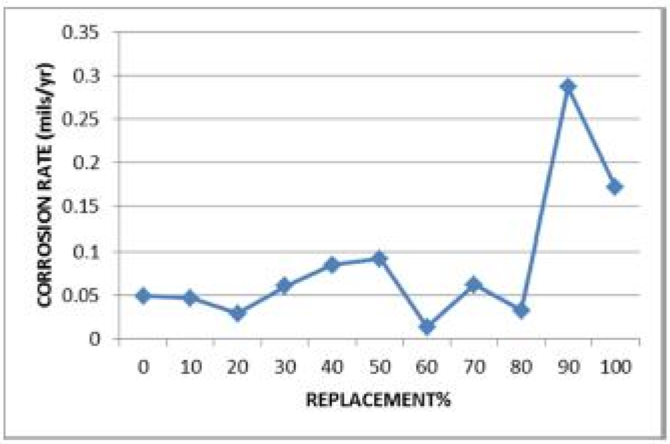
From the graphs obtained by conducting the corrosion analysis at the age of 28 days and the corrosion rates are obtained by setting out tangents to the curves obtained and the obtained and the values are given in figure 5.



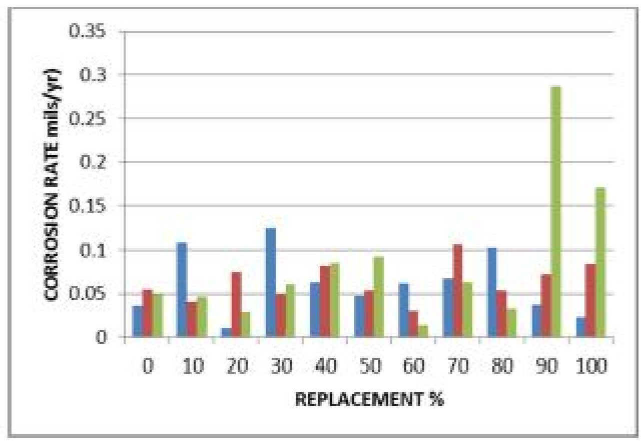
M30 grade concrete



M100 grade concrete



M100 grade concrete induced with polymer



Comparison of all three grade Concrete

Fig.5. Corrosion rate of steel bars embedded in concrete cubes

The Figure 4 shows that there is a constant increase in corrosion rate for M100 and M100 induced with polymer and in case of M30 mix there is a hike in corrosion value which is higher than the other two mixes. The highest corrosion rates is observed in M100 concrete induced with polymer. The peak corrosion value is observed at 90% replacement of quarry dust in M100 polymer induced concrete.

IV. CONCLUSIONS

From this study, it is concluded that the corrosion rate of rebar embedded in M30, M100 and polymer cement concrete was found to vary with respect to age of concrete and grade of concrete. The result shows that the M100 grade concrete shows lower corrosion rate than normal strength concrete. This may be due to lower permeability and hence the exchange of ions is less and this lead to the lower rate of corrosion. On the other hand the concrete with water soluble polymer exhibits very high rate of corrosion. This may be due to the fact that the effect of polymer in polymer cement concrete was dormant and hence higher rate of corrosion exhibits

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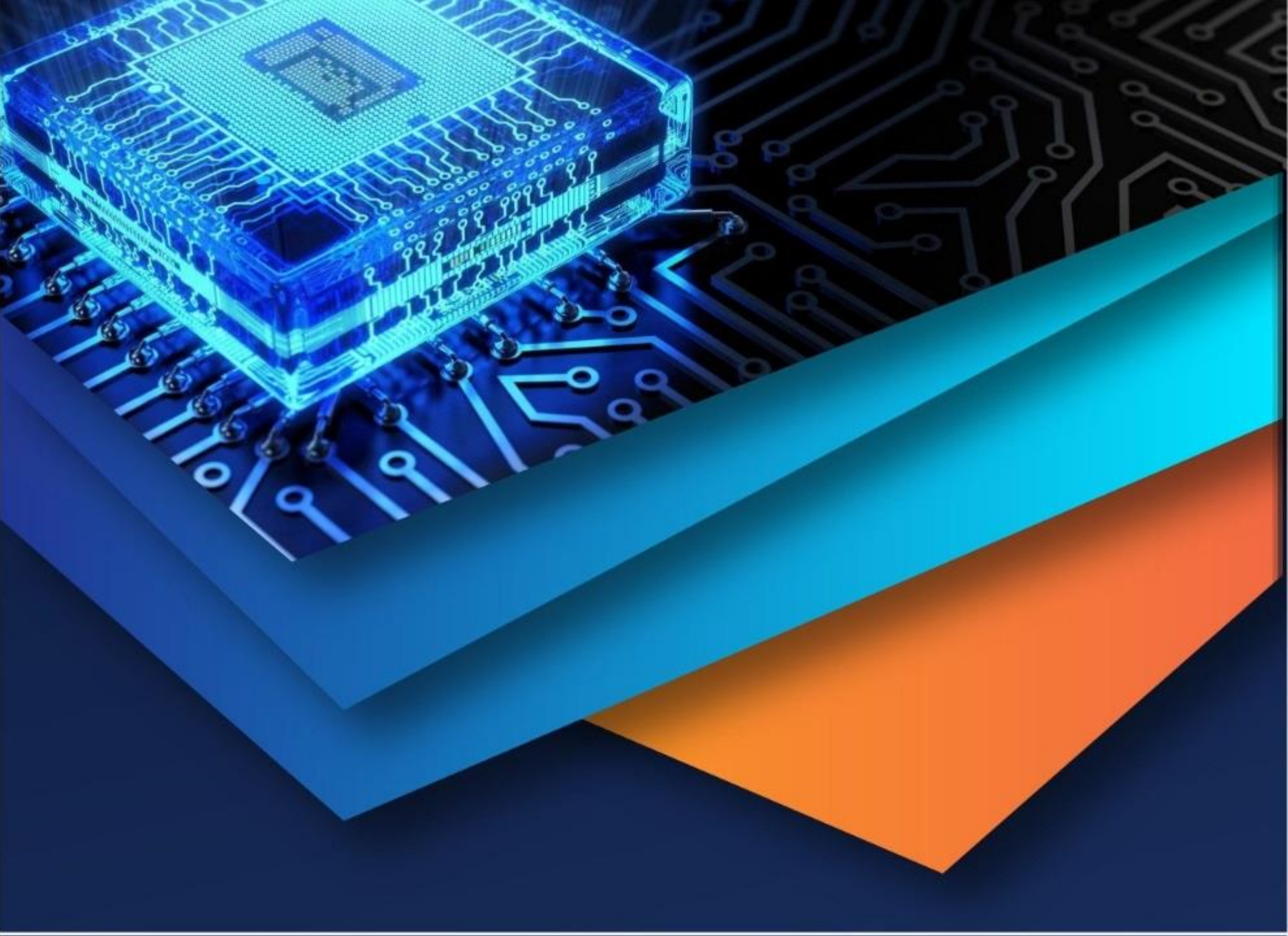

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