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Comparative Study of Corrosion Resistance of Polymer Modified Concrete and Concrete with Corrosion Inhibiting Agent

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***Abstract* - Now a days, various reinforced concrete structures due to rapid deterioration. Several deterioration causes and factors have been investigated in reinforced concrete structures. Corrosion of steel reinforcement is one of the major deterioration problems. The study has been made on corrosion resistance of polymer modified concrete with polymer (SBR latex) 10% such as with mineral admixture (Fly ash 30%, GGBS 30%, SF 8%) by volume of cement. Also the study will conducted for concrete with corrosion inhibiting agent (sodium nitrite 2%, Potassium dichromate 0.75%).Thus, the corrosion-induced initiation time and maximum anodic current intensity generated by corrosion process of embedded steel reinforcement in concrete were investigated in this paper. The objective of this study is to evaluate the corrosion resistance of polymer modified concrete and concrete with corrosion inhibiting agent using an acceleration corrosion cell. The corrosion cell proved to be good and simple method to evaluate the durability of concretes especially with respect to chloride ion penetration, and the protection of reinforcement against corrosion. Results proved that due to remarkable increase in time to cracking the polymer modified GGBS based concrete increases the durability and service life of concrete structures significantly.**

Keyword: Polymer SBR latex, Fly Ash, GGBS, Silica Fume, Sodium nitrite, potassium dichromate, Corrosion resistance.

INTRODUCTION

The subject of the concrete structures durability has extensively been studied and investigated for the last four decades. Chloride induced corrosion is a major of deterioration for structures exposed to marine environment or to deicing-salts. The concrete is popular building material in the world for past 170 years and more. Though worldwide used concrete has biggest disadvantages, such as delay in hardening, low tensile strength, large drying shrinkage and low chemical resistance. To overcome this disadvantages attempts is made by modifying cement concrete with polymer additives, such as SBR latex. Polymers are preferred in the cement composites due to high performance, multifunctionality and sustainability compared to conventional concrete. The penetration of chloride-ions in to concrete had been regarded as the major deterioration problem. In recent years, mineral admixtures or supplementary cementations materials are commonly used in concrete because they may improve durability. Even though the advantages of using mineral admixtures to control chloride permeability studied extensively. The addition of corrosion inhibitors one of the corrosion prevention methods used in order to delay the corrosion process. Corrosion inhibitor is a chemical substance which, in the presence of corrosive agent, decreases the corrosion rate in a corroding system when used at suitable concentration (Al-Mehthel et al, 2009; Revie and Uhlig, 2008; Holloway et al, 2004).This paper, therefore, studies the synergistic effect of the double combinations of $K_2Cr_2O_7$, $NaNO_2$ as inhibitors on the corrosion of steel-rebar in concrete partially immersed in sodium chloride medium. The main objective of this study comparative study of corrosion resistance of polymer modified concrete and concrete with corrosion inhibiting agent using acceleration corrosion cell.

EXPERIMENTAL INVESTIGATION

The material used for this experimental work are cement, sand, water, silica fume, Fly ash, GGBS, SBR (latex),Sodium nitrite, potassium dichromate

- Cement: Ordinary Portland cement of 43 grade was used in this experimentation conforming to I.S – 8112 -1989.
- Sand: Locally available sand zone III with specific gravity 2.63, fineness modulus 3.10, conforming to I.S. – 383-1970
- Coarse aggregate: Crushed granite stones of 20 mm size having specific gravity of 2.70, fineness modulus of 6.86, conforming to IS 383-1970
- Water: Potable water was used for the experimentation.
- Silica fume: Specific gravity of SF is 2.14.Silica fume is a waste material that generated during the manufacture of silicon or silicon ferrous. Silica fume is less than 0.5µm in size. The entire experimental study was performed using 940-U-type silica fume from the Elkem Company in Istanbul turkey.
- Fly ash: Specific gravity of FA is 2.58.Fly ash is composed of the mineral portion of coal.Particles are glassy, spherical 'ball bearing' finer than cement particles. Sizes of particles are 0.1µm-150µm.It is a pozzolanic material which reacts with free lime in the presence of water. The fly ash is produced from maize products power plant. This plant is located near kathwala in Ahmadabad district is Gujarat state.

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- GGBS: Specific gravity of GGBS is 2.95
- Sodium nitrite: specific gravity of SN is 2.17
- Potassium di chromate: specific gravity of PD is 1
- SBR (latex): The polymer latex used was styrene-Butadiene (SBR) From Fosroc-Egypt. The SBR is in a liquid

State of low viscosity having a solids content of 47%, PH of 11.0, and specific weight of 1.0. A dosage 5%, 10%, 15% solid latex material to cement by weight (p/c) ratio was used. The polymer latex used was added to the mixing water and added to the mixed dry concrete ingredients, and then mixing was completed for about 5 minutes.

1.Specimen preparations and curing

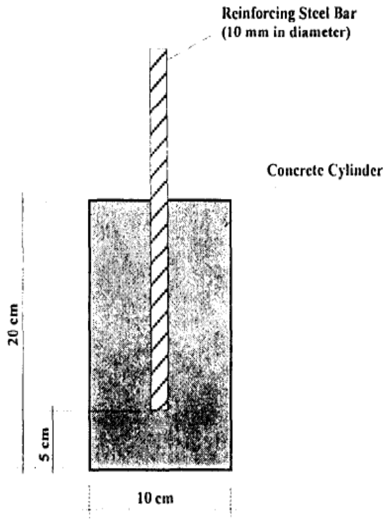

Fig.1 Schematic diagram of the lollipop Specimen

Table.1Lollipop Specimen

S. No	Specimen	Size
1	Cylinder	100x200mm
2	Steel	Dia 10mm
		length 250mm

The steel bar was embedded in to the concrete cylinders such that its end is at least 5cm from the bottom of cylinder.

2. Casting of cylinder

Fig.2Casting of specimens for cylinder

3. Curing method

The curing for polymer modified concrete is not similar to ordinary Portland cement. The specimens are cured under moist gunny bags for two days, immersion curing for five days and then air cured until the date of experiment.

EXPERIMENTAL TEST RESULT

Compressive strength test:

The bottom of the concrete cube is placed on the platform of the compressive testing machine. The load is applied gradually till the concrete cube gets failed. The corresponding reading is noted which gives the compressive strength of that cube. Similarly the compression strength values of all the cubes are found.

For each mix 3 nos cube of size 150mm are cast to the compressive strength using a 200T compressive Testing machine (CTM). Tests are carried out different ages on 28 days respectively. Tests are conducted as per I S516- 1959.

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Fig.3 Compressive Test Setup

Table.2 Compressive strength of cube tested at 28days

S. No	Type of specimen	Average compressive strength N/mm^2
1	CC	38.65
2	CP_{10}	33
3	$CP_{10}GGBS_{30}$	35.33
4	$CP_{10}FA_{30}$	34.98
5	$CP_{10}SF_8$	34.65
6	SN_2	35.78
7	$PDC_{0.75}$	35.23

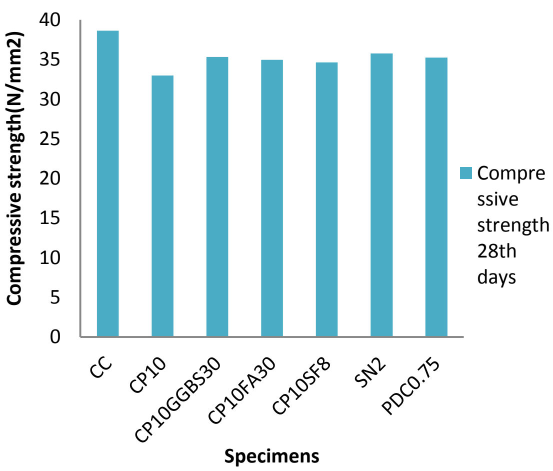

Fig. 4 28days results for compressive strength

Table.3 Flexural strength of prism tested at 28days

S. No	Type of specimen	Average Flexural strength N/mm^2
1	CC	4.50
2	CP_{10}	5.10
3	$CP_{10}GGBS_{30}$	5.82
4	$CP_{10}FA_{30}$	5.47
5	$CP_{10}SF_8$	5.45
6	SN_2	4.85
7	$PDC_{0.75}$	4.79

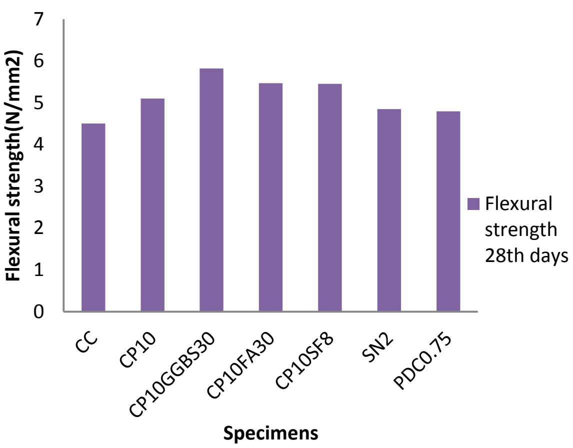

Fig.5 28days results for Flexural strength

Flexural strength test

The flexural strength can be obtained by using the following equation,

$Fcr = PL/bd^2$

L – Effective Length in mm

b - Breadth of beam in mm

d – Depth of beam in mm

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DURABILITY TEST

Acceleration corrosion cell test:

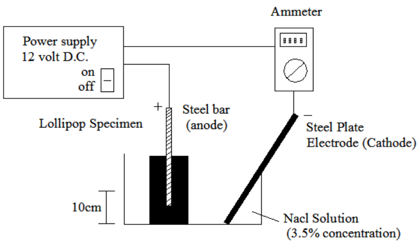

Fig.6 Schematic diagram of accelerated corrosion cell

In this cell the specimen was immersed to its half height in to a 3.5% sodium chloride (Nacl) solution at room temperature, and connected to a constant 12volt D.C power supply such that the steel bar acts as the anode. The steel plate electrode was used as cathode. The steel plate was cleaned periodically to prevent the deposition of calcium on the surface .In the acceleration corrosion cell the specimens are monitor periodically by visual inspection to record how long it takes to crack due to the corrosion of the reinforcing bar. Also, the intensity of the electric current was recorded at different time intervals.

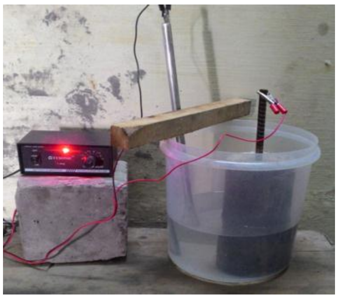

Fig.7 Specimens are tested in accelerated corrosion cell

TEST RESULT AND DISCUSSION

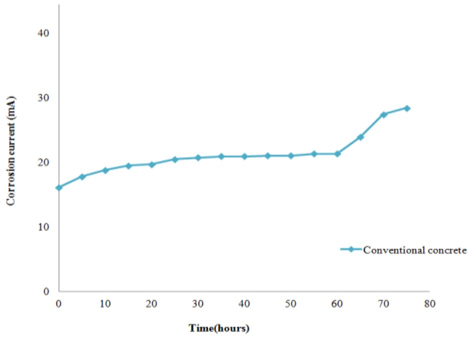

Fig.8 Typical curve of corrosion current with time for conventional concrete at 28test age

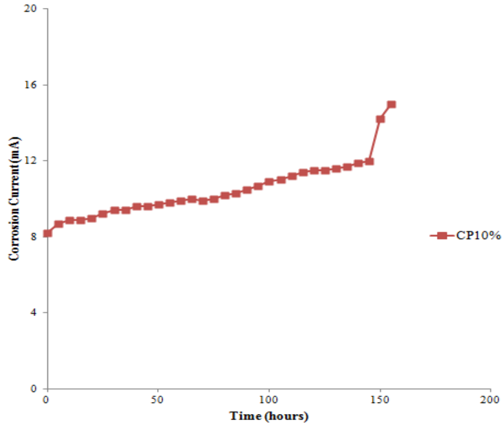

Fig.9 Typical curve of corrosion current with time CP_{10} at 28test age

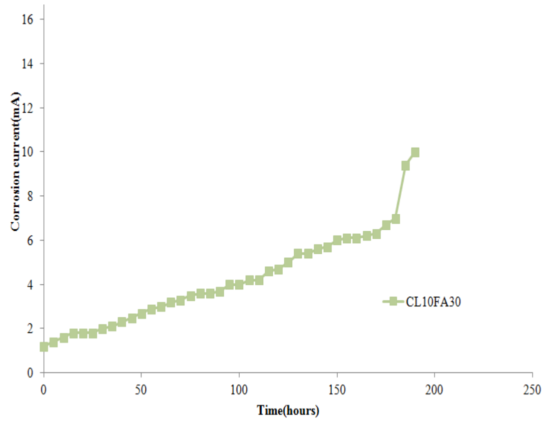

Fig.10 Typical curve of corrosion current with time CP_{10} FA_{30} at 28test age

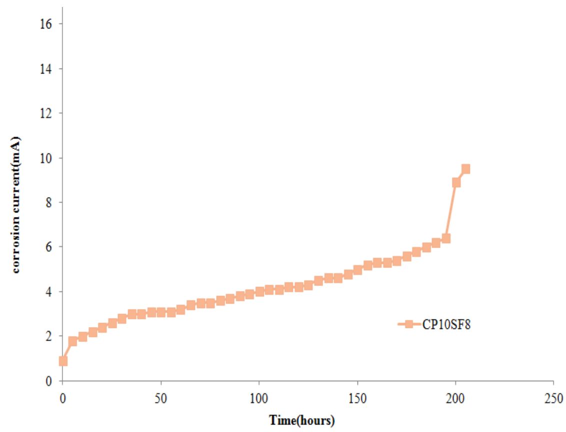

Fig.11 Typical curve of corrosion current with time $CP_{10}SF_8$ at 28test age

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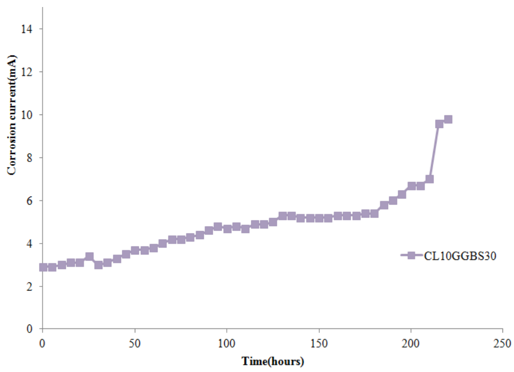

Fig.12 Typical curve of corrosion current with time CP_{10} $GGBS_{30}$ at 28test age

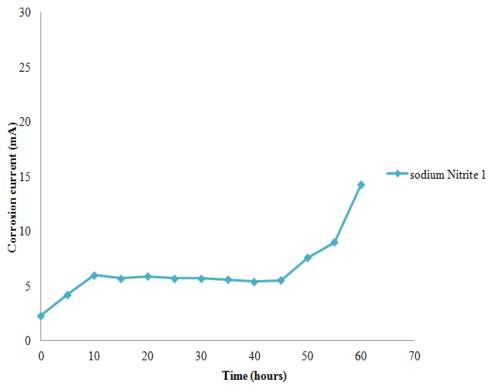

Fig.13 Typical curve of corrosion current with time Corrosion Inhibitor at 28test age

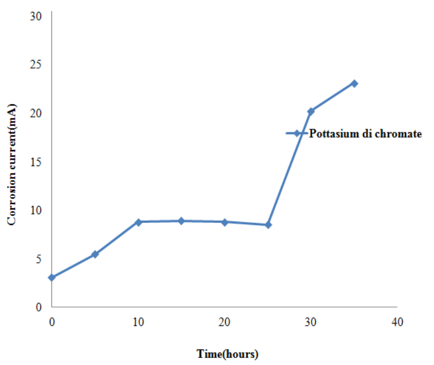

Fig.14 Typical curve of corrosion current with time Corrosion Inhibitor at 28test age

The corrosion current versus time relation has a steady low rate of increase in the current with time. The observed sudden rise of the current from the starting time of the experiment is referred as the corrosion time. The sudden rise of the current intensity of the specimen is recorded visually, when the crack has formed. A fast longitudinal crack has been recorded for the conventional concrete and corrosion Inhibitor concrete, where as a slow and curved multidirectional cracks are recorded for the modified concrete (Fly Ash, GGBS, and Silica Fume) based concrete. The specimen cracked due to the corrosion which is determined by the plotted curve between the corrosion current intensity (mA) and time (hours).

At the different test ages, the polymer modified concrete and polymer modified (Fly Ash, GGBS, and Silica Fume) based concrete shows better performance with increased corrosion time. The polymer modified concrete and polymer modified (Fly Ash, GGBS, and Silica Fume) based concrete has a higher electric resistivity compared to the conventional concrete and corrosion Inhibitor concrete, due to the decreased in the initial current intensity.

The polymer modified concrete fluctuation recorded for first 100 hours, where as conventional concrete specimen fluctuation has not observed. The fluctuation observed in the corrosion current is due to the decrease of permeability and absorption, by the addition of polymer to the concrete.

The conventional concrete specimens cell wetted at the upper portion, above the solution level at about 12 hours after setting the experiment. This could be attributed to the water blocking property, and blocking of moisture movement in the polymer modified concrete. The polymer modified concrete and polymer modified (Fly Ash, GGBS, Silica Fume) based concrete have a much longer time corrosion resistance to the conventional concrete of almost same strength level. Polymer modified concrete offers better protection to steel reinforcement against corrosion.

CONCLUSIONS

The different types of mix are tested using an accelerated corrosion cell and the values are noted visually. Table.4 shows the corrosion time for different types of concrete.

Table.4 Average Corrosion Time (Hours) For Conventional Concrete And Polymer Modified Concrete With Corrosion Inhibiting Agent.

Sl. No.	Concrete Type	Corrosion Time (Hours)
1	CC	75
2	CP_{10}	145
3	CP_{10} FA_{30}	190
4	CP_{10} SF_8	205
5	CP_{10} $GGBS_{30}$	220
6	SN_2	60
7	$PDC_{0.75}$	35

Accelerated corrosion cell proved to be a good and simple to test to assess the durability of concrete especially with respect to chloride ion penetration and steel reinforcement protection against corrosion. The corrosion resistance of the polymer modified concrete, and polymer modified (Fly Ash, GGBS, Silica Fume) based concrete increases significantly with increased amount of added latex, while that of convention concrete has a marginal increase. The polymer modified concrete and polymer modified (Fly Ash, GGBS, Silica fume) based concrete has a much corrosion resistance compared to the conventional concrete and corrosion Inhibitor. The higher resistance offers a better protection for the steel reinforcement against corrosion, and especially that

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induced by the penetration of the chloride ions, which recommended use of concrete in structures exposed to severe environments such as, bridges decks overlay, and marine structures.

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