COMPARATIVE STUDY ON THE CORROSION RATE OF REBARS EMBEDDED IN FIBRE REINFORCED CONCRETE AND FIBRE REINFORCED POLYMER CONCRETE

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Abstract - *One effective methodology for preventing corrosion of steel reinforcement and enhancing the mechanical properties of concrete is altering the physical properties of concrete by incorporating different materials. In this study, a banyan fiber as an additional material was used in conventional and polymer concrete. The corrosion rate of rebar was compared for different volume ratios of banyan fibers. It is found that the corrosion rate is increased with increasing banyan fibre content in the concrete. The corrosion rate decreases in fibre reinforced polymer concrete made with optimum polymer content (15%). For 5% fibre addition, the corrosion rate of rebar in polymer concrete was reduced 92% when compared to concrete of same fibre content.*

Key Words: Banyan fibre, fibre reinforced polymer concrete, Corrosion rate, Tafel graphs.

1.INTRODUCTION

It is usually understood that the originally protecting atmosphere that concrete provides for steel is because of the alkaline nature of concrete. This is often typically reflected in passive or nobler corrosion potentials for steel in concrete. When aggressive chlorides ions enter into concrete, the environment can become favorable for corrosion of reinforcing steel bar [1,2,3]. When aggressive chloride ions attain the critical quantity, the potentials become more active, and hence shifting in E_{corr} values is often related with the penetration of chloride ions. This is the reason for increasing of the corrosion rate. The embedding of rebar in concrete corrodes, the products of corrosion gradually collect around the circumference of the bar, occupying more space and applying pressure to the encasing concrete, leading to cracks. The crack widths grow in proportion to the percentage of reduction of rebar mass [4].There are noticeable cases where concrete will be disclosed in marine environments that are crowded with chloride ions [5-8].penetration of chloride ions into concrete that is exposed to the marine atmosphere will reduce over the period due to the hydration of cement in concrete, making the concrete pore structure more dense, or removing chloride ions by binding [9].

Other factors can also have influenced this phenomenon, namely the amount concrete cover, the method compaction and efficiency of curing, and the water/binder ratio (w/b), but it appears that permeability of concrete plays a vital role. The concrete permeability can be potentially decreased by incorporating polymer as cement replacement materials, adding fibers and the concrete encasement in a polymer resin [6]. In addition, fiber reinforced concrete has a prolonged service life while comparing with conventional concrete due to its resistance to corrosion and chemical attack [10]. The appearance of post-peak residual strength of concrete element in flexure was the best advantages of the adding fibers in concrete as secondary reinforcement [11].Electrochemical methods namely polarization curves and potentiometer data applied to steel-reinforced concrete can be very much helpful in analysing the effect of the aggressive ions intrusion on the corrosion rate of the steel embedded [12,13].The controlling of the crack width for enhancing durability of concrete can be a main parameter for designing reinforced concrete element [14,15]. Particularly, unpredicted cracking can be seen as a result of steel corrosion, which leads to a prematurely decreased service life for a reinforced concrete structural element [16].Also the use of polymer and fibre can cut down cracking due to shrinkage in cement mortar or concrete members [3]. Pelisser et al [15] analysed the addition of different types of fibers in concrete, and they revealed that crack formation can be reduced significantly.

In this study, the use of banyan fibe and its influence on corrosion rate of rebar in both conventional and polymer concrete were experimented. Following this, the study of corrosion rates by electrochemical methods, and measuring the permeability of the concrete cover of the reinforcement and concrete electrical resistivity were investigated.

2. EXPERIMENTAL PROCEDURES

2.1. Materials

2.1.1. Cement

The Ordinary Portland Cement of 53 grades from Ramco cement brand conforming to IS: 12269:1987 and IS: 8112-1989 is used in this experimental project. The normal consistency of cement is 30% and the initial setting time of cement is160 minutes and the final setting time of cement are 320minutes. The specific gravity of cement is 3.15.

2.1.2. Coarse aggregate

The fraction of aggregates used in the experimental work passed in 20mm sieve and retained on 10mm IS sieve comes under Zone II aggregates conforming to IS: 383-1970. Naturally available granite stones are crushed into desired size and used in this work hand broken stone jelly with angular edges and satisfying flakiness and elongation index are used in this experimental work.

2.1.3.Fine aggregate

Sand which passes through 4.75 mm IS sieve and retained on 75micron IS sieve is termed as fine aggregate. Fine aggregate added to concrete to assist workability and to bring uniformity in mixture. Usually, the natural river sand is used as fine aggregate. Ordinary river sand confirming to IS 383 – 1970 is used in this study.

2.1.4.Water

Water used in making concrete should be free from impurities and PH of the water should be 6.5- 8. It is important that water is added based on the water- cement ratio as adopted in mix design or standards. Potable water available in the concrete laboratory was used for mixing of concrete materials.

2.1.5. Polymer

Chemical synthesis of water soluble polymer p-phenylene diamine was used.

Solution preperation

(i) 2.162g of p-phenylene diamine salt is taken and is mixed with 200ml of distilled water and 2ml of Hcl is added to the mixture. This mixture is stirred well until a clear solution is obtained.

(ii)3.804g of p-toluene sulphuric acid salt is taken and mixed with 200ml distilled water. This mixture is stirred well until a clear solution is obtained.

(iii)4.562g of ammonium per sulphate is taken and mixed with 200ml distilled water. This mixture is stirred well until a clear solution is obtained.

Polymer preparation

(i)The above said solutions are used to prepare polymer

(ii)A two liters beaker is taken and is kept in freezing mixture (Sodium Chloride + ice cubes)

(iii)The solutions p-toluene sulphuric acid and p-phenelylene diamine solutions are added to beaker and it is stirred for 10 min.

(iv)Then the solution Ammonium per sulphate solution is added to mixture and it is stirred for about two hours. After two hours polymer named poly Para phenylene diamine is obtained. It is water soluble and has concentration of 3605ppm.

(v)From the obtained above solution 100ml is taken and is mixed with 600ml water. The resulting polymer solution has a concentration of about 500ppm.

Fig.2.1 Chemical used in the polymer preparation

Fig.2.2 Polymer preparation Setup

Fig.2.3 Polymer formation

2.1.6. Banyan fibre

Banyan is found in almost all the parts of India. It is grown throughout the sub-Himalayan region and in the deciduous forests. It is drought resistance. It is a fast growing tree. It can be easily propagated. Banyan tree is easily propagated by root tip cuttings or eye cuttings. It can grow in any type of soil. Banyan has nearly eight species and the species ficus benghalensis is used in this study. Older banyan tree are characterized by their aerial prop roots that grow into thick woody trunks. Aerial prop root is choosen as the fibre in in this project.

Pulping of prop roots

(i)The banyan prop roots were cut down from the banyan tree and were chopped into pieces of 30 cm for easy transportation.

(ii).Then they were beaten using a wooden mallet to separate bark from the stem and then dried in shade for a week

(iii).Then these roots were soaked in water for about 2 months.

(iv).Pulping is done in room temperature. The bark and the stem are soaked separately.

(v)The microorganisms will act on them which will help in the separation of fibres.

Extraction of fibres

(i).After 2 months the soaked roots are washed in fresh water and was subjected to mechanical treatment, by beating them gently with wooden mallet in order to loosen and separate the fiber.

(ii).The resulting fiber bundle was scrapped with sharp knife and combed until individual fibers were obtained.

Aspect ratio:

(i) It is an important property of a fiber which determines the strength of FRC.

(ii)A limiting aspect ratio of 75 is preferable above which the strength and toughness gets reduced

Aspect ratio = length / diameter

0.75 cm / 0.125 mm = 60

(iii)Aspect ratio of our fiber is 60 and it`s diameter is measured using microscope.

(iv)Then the extracted fibers were cut using scissors to the needed length.

Fig.2.4. Fibres extracted

Fig.2.5. Fibres of required aspect ratio

2.2. Mix design and Methods

This experiment is being investigated by using same brand steel bars embedded in three concrete mixes namely conventional concrete, fibre reinforced concrete and fibre reinforced Polymer concrete.

Concrete of M30 grade with w/c ratio of 0.5, were used for conventional concrete. In M30 mix banyan fibre of varying proportion namely 1%,2%,3%,4% and 5% by weight of cement were used.

Polymer concrete of M30 grade concrete with optimum polymer of 15% (replaceable of water) was prepared. In polymer concrete, banyan fibre of varying proportion namely 1%,2%,3%,4% and 5% by weight of cement were used.

The materials of required quantities were measured and taken as per the design mix and mixed thoroughly in the mixing pan. The concrete was then placed in the cube and compacted using vibrator for half level and then the bars were then placed in the centre of the cube and remaining concrete is compacted by tamping rod. After that the cubes were demoulded after 24 hours of casting and placed for curing.

Corrosion measurement

The following steps have to be followed to carry out the carrion analysis of the bars embedded in concrete.

(i) The instrument used for the test is GILL AC SERIAL NO 1829.(fig.2.1)

(ii)The connections from the instrument to the computer are to be done and the necessary software has to be installed.

(iii)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.

(iv)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.

(v)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 connected to the bars by means of the wire. Then the connection is checked by the use of multimeter

(vi)After the connections are made the connections are checked by "Rest Potential". The difference in values should not be greater.

(vii)Then the "Gill AC Serial No 1829 Sequencer" is opened and the required operations are sequenced.

(viii)First the area of the specimen and the destination where the file is to be saved is entered.

(ix)For our project only two processes are used, first the "Current & voltage/time" is set up by entering the reading per test and cell settle .

(x) The second process is "Long Term – LPR Sweep" and it is set up by changing the values of sweep rate and cell settle time.

(xi)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.

(xii)After clicking Run Now, the Core Running opens and the process will start as it is listed in the sequencer.

(xiii)Once all the processes are finished the values has to be analysed.

(xiv)The "Analyser" is opened to take the values.

(xv)After opening the analyser the desired data is selected and for the selected data the graphs appear.

(xvi)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.

(xvii)The selected graph opens in an enlarged view and the type of graph is changed to "Tafel" graph.

(xviii)After the tafel graph opens the tangents to the curve are fixed by using "Tafel Rulers".

(xix)The values are stored by clicking the auto button and to take the values the "Data Bank" is opened.

(xx)In the data bank the required values are taken.

(xxi)The process for the required number of specimens and cycles

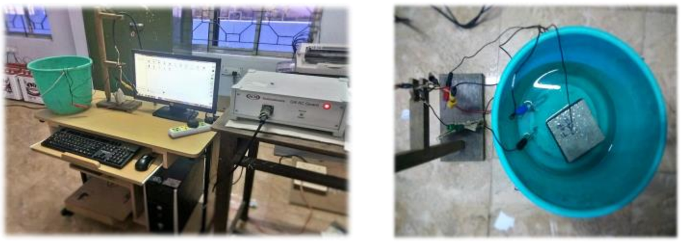

Fig.2.1. GILL AC SERIAL NO 1829 instrument setup

3. RESULTS AND DISCUSSION

The corrosion test was conducted on rebars embedded in Conventional concrete, Fibrereinforced concrete and Fibrereinfored Polymer concrete and the following graphs were obtained. With help of that, we obtained corrosion values by using "Gill AC Serial No 1829" instrument and its software.

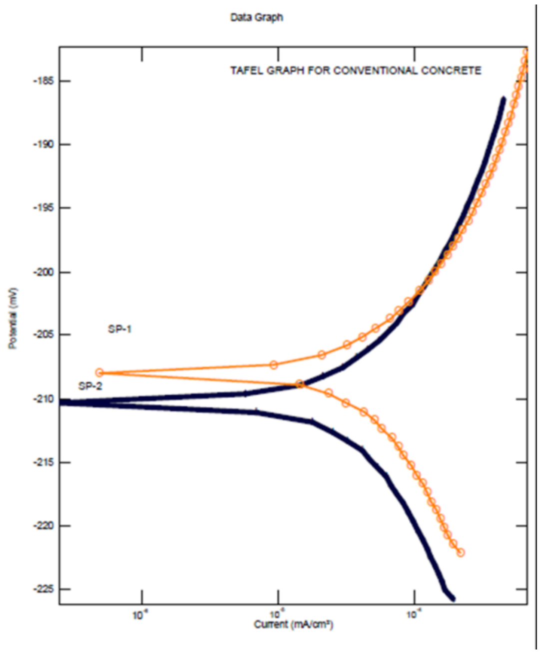

Fig.3.1. Tafel graphs for conventional concrete at 7 day

3.1. Corrosion potential

The effect of volumetric ratio of banyan fibers on corrosion behavior of concrete samples with different volumetric ratios of fibers in both fibre reinforced concrete and polymer fibre reinforced concrete are shown in Figs. 3.1–3.9. The corrosion potential of conventional concrete is decreasing with the age of concrete. At 21 days the corrosion potential is less when compared to 7 days.

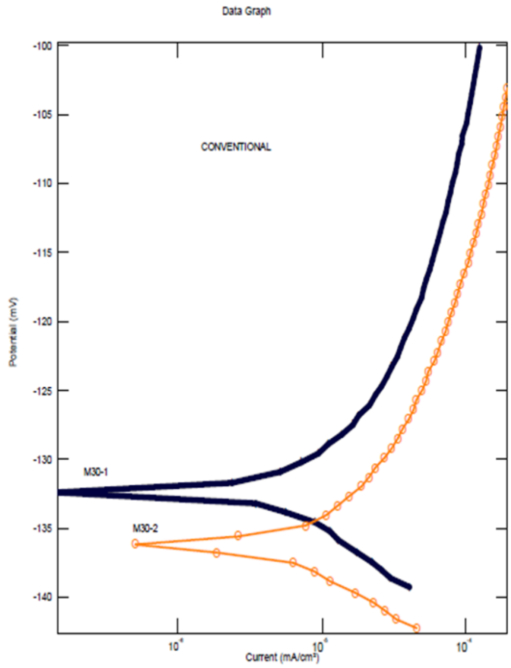

Fig.3.2. Tafel graphs for conventional concrete at 14 day

In fibre reinforced concrete, the concrete sample with 1% fibers had the least potential in comparison to the other concrete samples. The corrosion potential of banyan fibre reinforced concrete is increasing with the increasing fibre content. The sample with 5% fibre was very prone to corrosion as the curves show very high corrosion potential

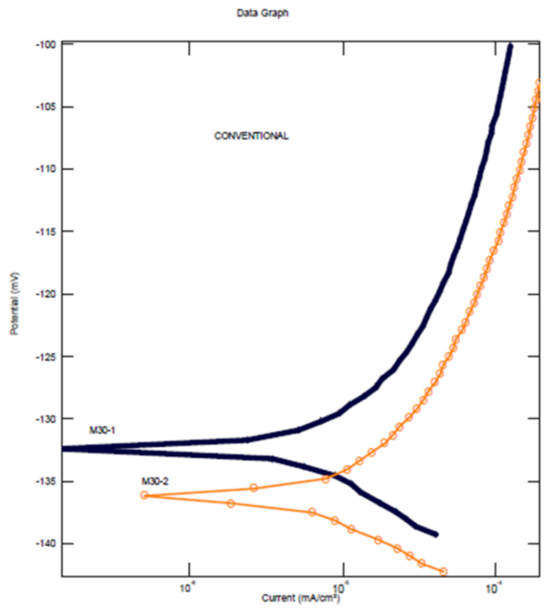

Fig.3.3. Tafel graphs for conventional concrete at 21 day

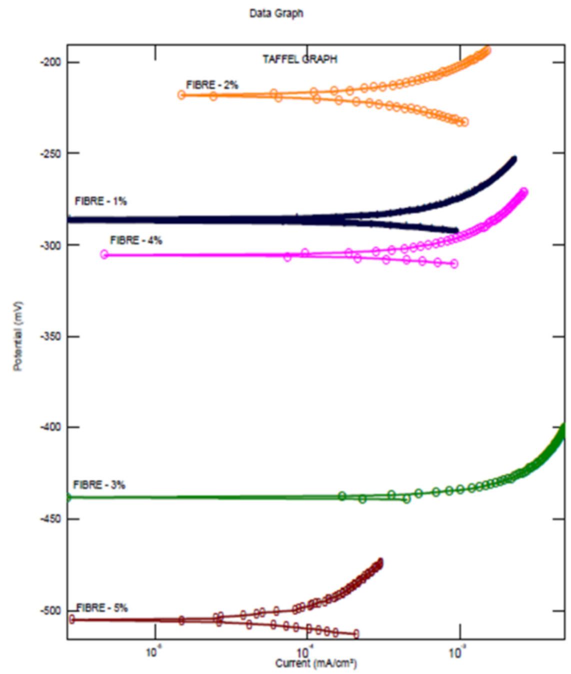

Fig.3.4. Tafel graphs for fibre reinforced concrete at 7 day

. In fibre reinforced polymer concrete also, the corrosion potential is increasing with increasing fibre content except the sample with 3% banyan fibre. The sample with 3% banyan fibre, has the least corrosion potential when compared to other samples.

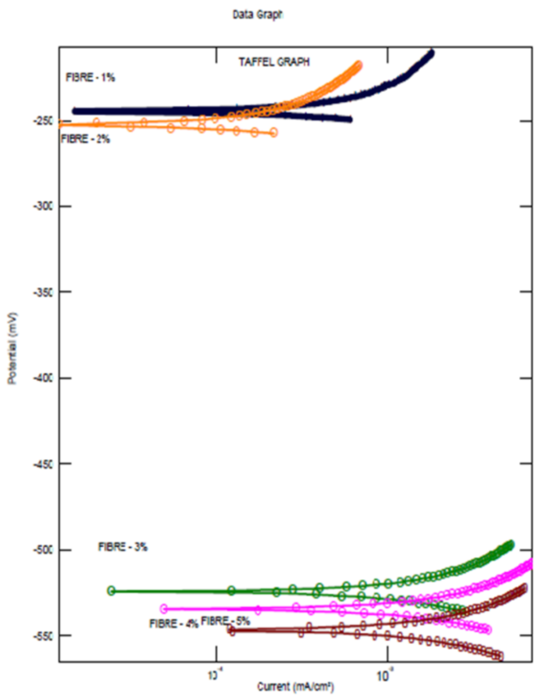

Fig.3.5. Tafel graphs for fibre reinforced concrete at 14 Day

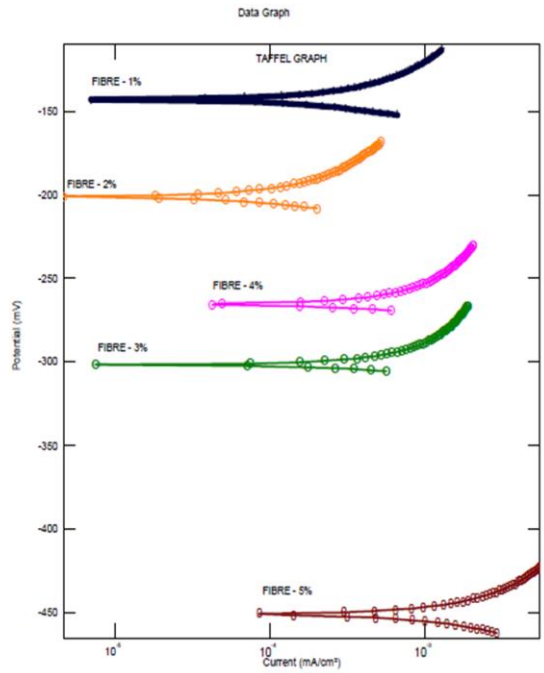

Fig.3.6. Tafel graphs for fibre reinforced concrete at 21 Day

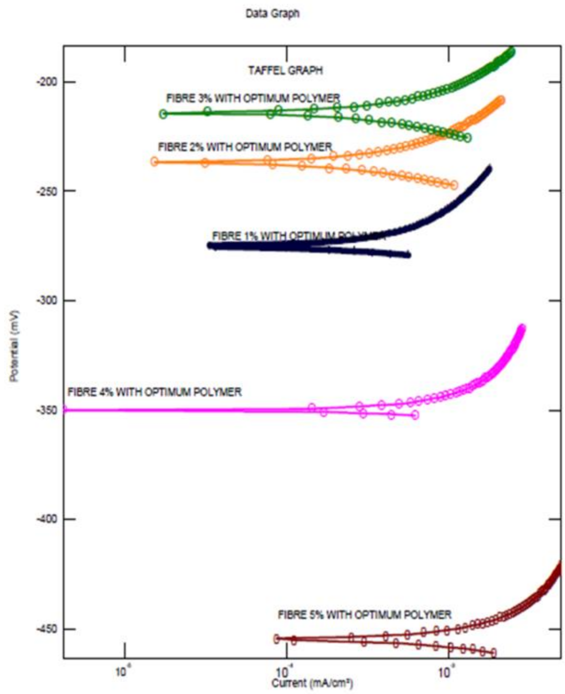

Fig. 3.7. Tafel graphs for fibre reinforced Polymer concrete at 7 day

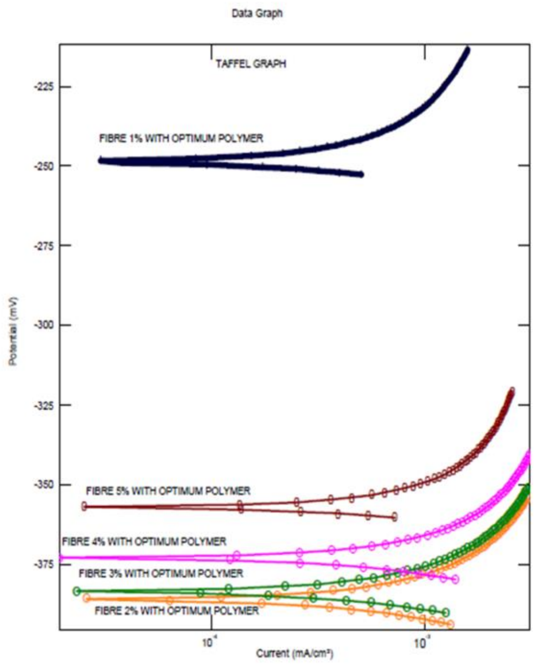

Fig. 3.8. Tafel graphs for fibre reinforced Polymer concrete at 14 day

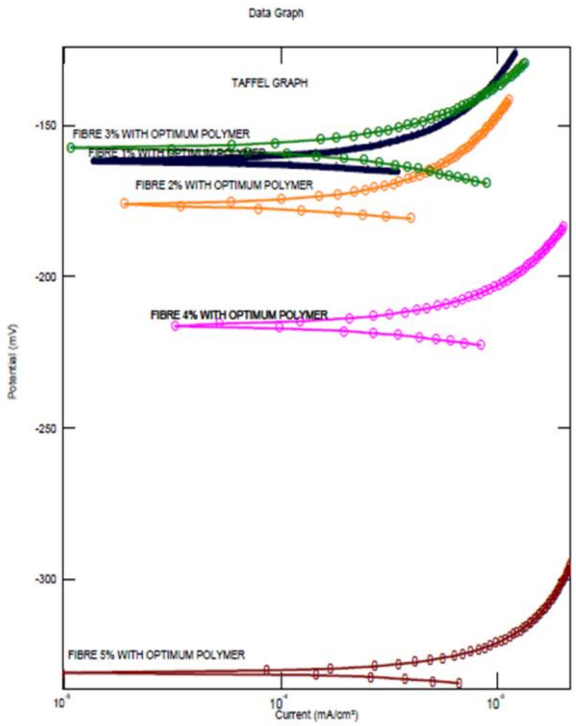

Fig. 3.9. Tafel graphs for fibre reinforced Polymer concrete at 21 day

Table 3.1 to 3.2 shows the corrosion rate of FRC and FRPC at 7, 14 and 21 days. It was observed that the corrosion rate of fibre reinforced polymer concrete is very less when compared to fibre reinforced concrete.

Table 3.1 Corrosion Rate of Steel Bars Embedded In Concrete Cubes (7days)

S.No	Fibre	FRC(mils/year)	FRPC(mils/year)
1	1%	0.0427231	0.0178885
2	2%	0.0271482	0.0668696
3	3%	0.1695868	0.0659686
4	4%	0.0477595	0.0909937
5	5%	0.0057048	0.2924148

Table 3.2 Corrosion Rate of Steel Bars Embedded In Concrete Cubes (14days)

S.No	Fibre	FRC(mils/year)	FRPC(mils/year)
1	1%	0.053056	0.0428772
2	2%	0.0195022	0.1114945
3	3%	0.1216864	0.1150316
4	4%	0.2095972	0.1403222
5	5%	0.2720544	0.0593968

Table 3.3 Corrosion Rate of Steel Bars Embedded In Concrete Cubes (21days)

S.No	Fibre	FRC(mils/year)	FRPC(mils/year)
1	1%	0.0361274	0.0198894
2	2%	0.0197911	0.0425484
3	3%	0.0423389	0.0683639
4	4%	0.0491789	0.05111
5	5%	0.2762302	0.0226941

3. CONCLUSIONS

In this study, it is found that the corrosion rate FRC is increased within increase in fibre content. By contradictory the corrosion rate increases with increasing fibre content upto 3% and then decreases when an optimum polymer content of 15% was added . The lower permeability of FRC due to polymer addition is attributed to the decreased corrosion rate. The rate of corrosion of rebar in FRPC at a polymer content of 15% and fibre content of 5% is nearly reduced to 92% when compared to FRC of same fibre content.

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