# AN EXPERIMENTAL INVESTIGATION ON CORROSION BEHAVIOUR OF REBARS COATED R.C. STRUCTURES

A.Vimaldurai[1], A Jayapal[2]
Student, Professor
Department of Civil Engineering,
Paavai Engineering College,
Namakkal,Tamilnadu India.

***Abstract*- Most of the facilities in the service is subject to aggressive effects on the environment. These corrosive attacks cause the structures to cause damage and lead to the failure of the structural element or the entire structure. Corrosion causes material deterioration and leads to destruction of structures, particularly in coastal and industrial areas. Steel corrosion is an electrical chemical phenomenon. Electrochemical corrosion results in the presence of various metals of asymmetry in steel or asymmetry in the chemical or physical environment provided by the surrounding concrete. This project aims to prevent R.C.Slabs decay through anti-corrosive agents, providing zinc to wear on metal walls. CR Planks or the size of 0.5m x 0.5m were thrown and controlled by rapid heat in the form of maturity. Extraction rates are employed using half-cell potentiometers. Updating what they do on R.C. These tiles were thrown in rotting clothes. The results were compared with the filing of pollution and the growing time.**

***Keywords*- Corrosion, Coating, R.C.Slab, Rebars, Materials**

## I.INTRODUCTION

Concrete is a building material that is mainly used by man in the world. It is collected by mixing material, water, aggregates in the necessary dimensions. It has high compressive strength and low tensile strength for developing stress when retracting concrete with reinforced steel bars called reinforced concrete with cement. Corrosion of the reinforcement is the main cause of the deterioration of structural concrete and the great economic cost of maintaining national infrastructures. The effect of deteriorating residual capacity is therefore worrying for those who are in charge of ensuring the safe operation of concrete structures. However, it is clear that many reinforced concrete structures remain in use until the armour starts to corrode and covers the concrete on the rods began to recover, there is ample evidence that modest amounts of corrosion do not pose a significant threat to structural stability. It is essential that responsible engineers have at their disposal the means available to check whether the affected structures maintain an acceptable safety margin. Corrosion can affect the residual capacity through some mechanisms, including the loss of a part of the rod, the loss of the concrete part as a result of longitudinal cracking and melting, and the reduction in the interaction or connection between the reinforcement and the concrete.

### *1.1Corrosion*

Corrosion is defined as the destruction of material due to chemical reaction with the environment, and also the loss of steel due to the formation of rust.

The corrosion of steel reinforcement is the depassivation of steel with reduction in concrete alkalinity through carbonation. Most material undergoes corrosion on exposure to natural environments (such as air, water, and soil) or other artificial environments (such as gases, liquids, and moisture).

### *1.2Corrosion process*

Corrosion of steel is an electrochemical phenomenon. Electrochemical corrosion results because of the existence of different metals or non-uniformities in steel or non- uniformities in chemical or physical environment, afforded by the surrounding concrete. This electrochemical corrosion is believed to be the predominant case for essentially all of the corrosion that occurs. The initiation of corrosion process is shown in Figure 1.

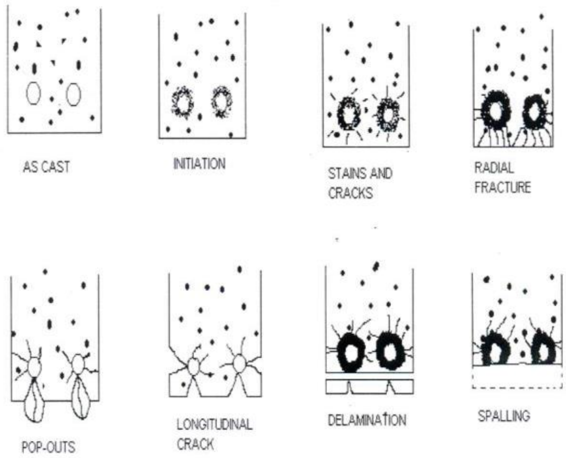


Figure 1. Typical Symptoms of Corrosion in a RC beam

*1.3Corrosion Mechanism*

Corrosion of steel in concrete is initiated and maintained generally by two mechanisms.

**i)** Presence of depassivating ions (particularly chlorides) in large enough amounts to destroy passivating films locally.

ii) Reduction in alkalinity of concrete (pH around 9.5) due, to the effect of atmospheric carbon-di-oxide.

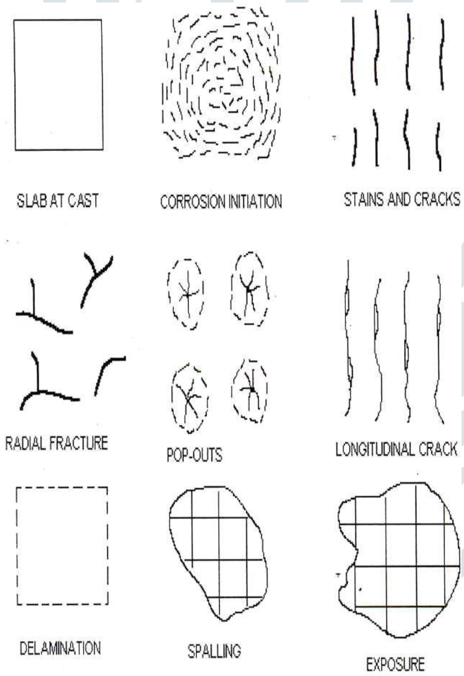


Figure 2. Typical Symptoms of Corrosion in a Reinforced Concrete Slab

$Fe \rightarrow Fe^{2+} + 2e^-$ (at Anode)

$0_2+2H_20+4e^- \rightarrow 40H^-$ (at Cathode)

$Fe^{2+}+20H^- \rightarrow Fe(OH)_2$ (at Anode) $4Fe(OH)_2+2H_20+0_2 \rightarrow 4Fe(OH)_3$ (at Anode)

(Hydrated red rust)

$3Fe+80H^- \rightarrow Fe_30_4 +8e^- +4H_2O$ (at Anode)

(Black rust)

Current flows in the steel from anode to cathode in the presence of oxygen and water and results in the production of hydroxyl ions at the cathode.

As these migrate to the anode they react with ferrous ion and form hydrous ions oxide (Black rust). The red rust is responsible for the cracking of concrete because its volume is four times larger than that of steel, while the black rust volume is only twice as large as steel..

*1.4Factors Influencing Corrosion*

a) Concrete quality
b) Chloride content
c) Alkalinity of concrete
d) Resistivity of concrete

e) Cover thickness
f) Sea Water Attack (Environment)

*1.5Methods of Corrosion Control*

a. Corrosion control by mix proportions:
b. Corrosion control by coatings:

Coatings may be of the following types

1) Organic coating on rebars
2) Inorganic coatings on rebars
3) Metallic coatings on rebars
4) Coating on concrete

Concrete surface *coatings may be of the following types:*

i) Inorganic coatings
ii) Organic coatings

c. Cathodic Protection
d. Corrosion inhibitors:
e. Stainless Steel Reinforcement:
f. Chloride content

*1.6Causes for corrosion*

1) Surface heterogeneity
2) Impurities, grains and grain boundaries, cut edges
3) Environmental variations
4) Industrial: $H_2S$, $NH_3$, $SO_2$
5) Marine: salt
6) Urban

## II.MATERIALS

*2.1Cement*

Cement is the most important constituent of concrete, in that it forms the binding medium for the discrete ingredients made out of naturally occurring raw materials and sometimes blended with industrial wastes. OPC cement of 53 grade is used for experimental study.

*2.2. Fine Aggregate*

The fine aggregates smaller than 4.75mm sizes are used. River sands are generally used as fine aggregate river sand was used in preparing the concrete as it was locally available in sand quarry. The specific gravity and water absorption were found to be 2.7 and 1,0% respectively, with sieve analysis data and fineness modulus value of sand confirms to grading zone II as per IS 383-2009.

*2.3.Coarse Aggregate*

The coarse aggregate retained on 4.75mm sieve are used. Crushed stone and natural gravel are the common materials used as coarse aggregate for concrete. It is obtained by crushing various types of granites, schist and gneiss, crystalline and lime stone and good quality sand stones. Concrete made with sand stone aggregate give trouble due to cracking because of high degree of shrinkage. For coarse aggregate crushed 20mm, normal size grade aggregate was used. The specific gravity and water absorption were found to be 2.7 and 0.5% respectively.

*2.4.Fibre*

Polypropylene fibres are used to improve the protection of concrete. It is a 100% synthetic textile fibre. It is formed by 85% propylene. This fibre is in white colour. The specific gravity of fibre is 0.91.The length of the fibre used is 2cm.

*2.5. Reinforcing steel*

Fe 415 HYSD bars of 8 mm diameter were used as reinforcement in the slabs.

Figure 3. Mixing of ECC concrete.


Figure 4. Materials used

## III.SCOPE AND OBJECTIVE OF THE PRESENT STUDY

The slabs are of a variety of design and were constructed to different specifications. The slabs increase in service in more than 100 years and are experiencing deterioration on various accounts. The scope of this work will bring out some of the facts related to slab corrosion and in turn will help in implementation of suitable corrosion preventing strategies.

Basically there are three protection techniques which prevent the corrosion of rebars in concrete.

a) Changing the environment around the reinforcing steel, by decreasing the amount of chloride reaching the rebar to a value low enough to retard or prevent corrosion.
b) Changing the nature of rebar surface so as to resist corrosion, either by surface treatment or bulk alloying.
c) Changing the electrochemical nature of the surface of the rebar by impressed current (cathodic protection).

## IV.EXPERIMENTAL INVESTIGATIONS

The method used to induce corrosion is galvanostatic method (accelerated corrosion method)

### *4.1. Experimental Setup - Accelerated Corrosion Test*

In M30 grade eight slabs were casted and the insulated copper wires are connected to the main reinforcement of the slabs at the corresponding points while casting. The metal above the steel in galvanic series can be used as sacrificial anode current is passed in reinforcement of slabs after filling the top of the slabs with salt water, which contains 3% of sodium chloride. The current is passed from a DC power supply. Positive terminal of the DC power supply is connected to the main reinforcement of the slabs and negative terminal is connected to the steel plate, which also kept immersed in the salt water.

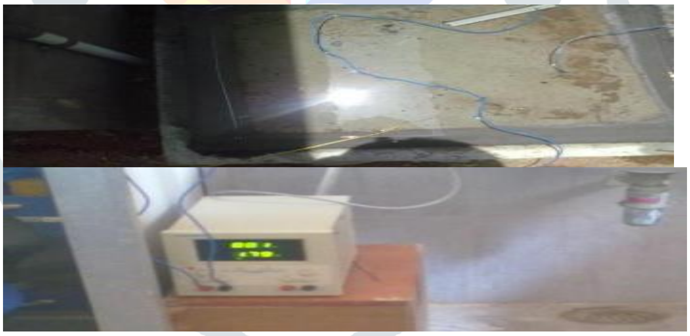

Figure 5. Supply of current from dc convertor to metal and reinforcement

### *4.2.Half-Cell Measurement*

The basic principle of this method is derived from galvanic cell theory. The slabs were partially immersed in 3% NACL solution. The slabs were subjected to corrosion by supplying from external D.C source.

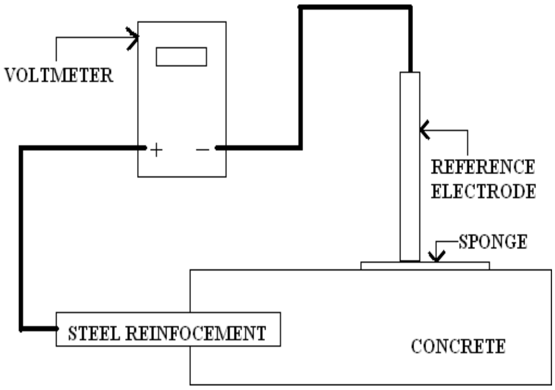


Figure 6. Half Cell Measurement Circuit

The density of current is around 1.8 to 2.0 mA/cm$^2$ of the surface area of the rod was induced corrosion. The slabs placed in the tank were subjected to a current density of 1.8 mA/cm$^2$ from external D.C source. The stainless steel plate which acts as cathode was placed below the slab. The stainless steel plate was 1.5mm thick. The current density was adjusted using knobs provided in D.C rectifier to maintain a constant current density throughout the test.

4.3. *Method of Preparation of Half- Cell*

- Check the electrical continuity of the cell between copper rod and terminal of the wire which is connected at the copper rod.
- Clean the copper rod using emery sheet to obtain the red color surface of the copper rod free from sulphate coating.
- Prepare saturated copper sulphate solution using copper sulphate crystals with glass beakers and glass stick.
- Remove the half-cell cover and fill with copper sulphate solution in the half-cell tube and close cover tightly.
- Keep the cell unit vertically for about 5 to 10 minutes so that the copper sulphate solution should permeate through sponge bottom of the cell.

Figure 7. Specimens Reinforcement Details

Figure 8. Experimental test setup

V.RESULT AND DISCUSSIONS

*5.1. Compressive Strength*

The specimens used were standard cubes of size 500*500*500mm. Tests were conducted using compression testing machine of capacity 300T. The loading was applied gradually and the results have been tabulated as in table 1.

Table 1. Characteristic Compressive strength for conventional and fibre concrete

| Details of specimen | Compressive strength for 7 days (N/mm$^2$) | Compressive strength For 14 days (N/mm$^2$) | Compressive strength for 28days (N/mm$^2$) |
|---|---|---|---|
| Conventional | 23.88 | 25.61 | 27.11 |
| With Fibre | 31.55 | 34.87 | 37.11 |

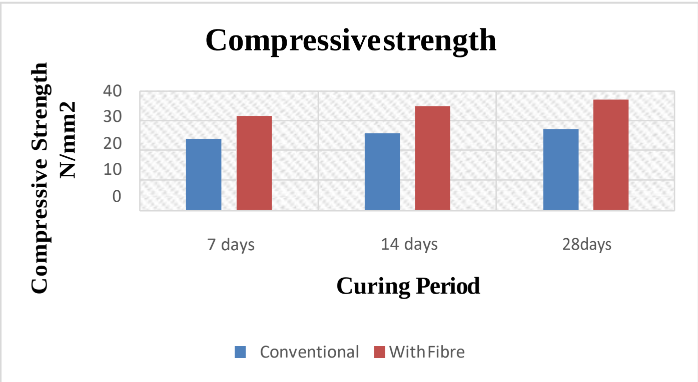


Figure 9. Chart comparing the compressive strength of conventional and fibre concrete

*5.2.Split Tensile Strength*

This test is carried out by placing the standard cylinder specimen of diameter 150mm and height 300mm horizontally between the loading surface of the compression testing machine and the loading was applied until the failure of the cylinder. Table 2 shows the test result for split tensile strength concrete for M25 concrete.

Table 2. Split Tensile strength for conventional and fibre concrete

| Details of specimen | Split Tensile Strength for 7 days (N/mm$^2$) | Split Tensile Strength for 14 days (N/mm$^2$ ) | Split Tensile Strength for 28 days (N/mm2 ) |
|---|---|---|---|
| Conventional | 1.8 | 2 | 2.2 |
| With Fibre | 2.5 | 2.7 | 3.0 |

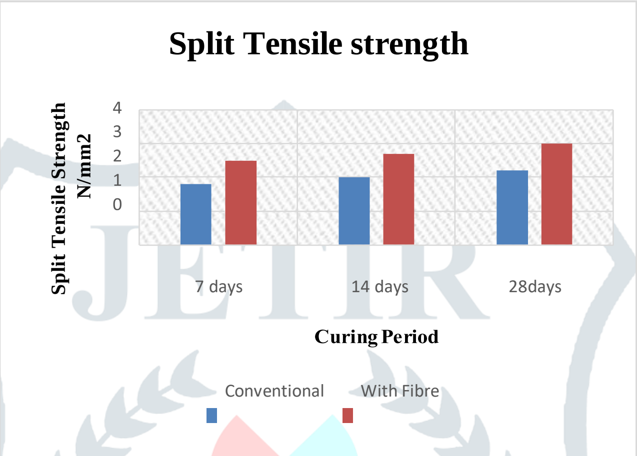


Figure 10. Chart comparing the split tensile strength of conventional and fibre concrete

*5.3.WEIGHT LOSS*

5.3.1Uncoated

Table 3. Weight loss for uncoated reinforcement specimens.

| S. no | Details of specimen | Initial wt (gms) | Final wt (gms) | % weight loss |
|---|---|---|---|---|
| 1 | M 25(con) | 175 | 164 | 6.28 |
| 2 | M25 + FIBER | 178 | 166 | 6.74 |

*5.3.2.Coated*

Table 4. Weight loss for coated reinforcement specimens.

| S. no | Details of specimen | Initial wt (gms) | Final wt (gms) | % weight loss |
|---|---|---|---|---|
| 1 | M 25(con) | 189 | 182 | 3.70 |
| 2 | M25 + FIBER | 186 | 181 | 2.68 |

Table 5. Half-cell reading for uncoated conventional reinforcement

| Time Intervals | M 25 | | |
|---|---|---|---|
| | Trial I | Trial II | Trial III |
| 0 | - | - | - |
| 25 | 24 | 19 | 30 |
| 50 | 54 | 64 | 113 |
| 75 | 77 | 74 | 86 |
| 100 | 110 | 116 | 118 |
| 125 | 130 | 138 | 138 |
| 150 | 153 | 167 | 178 |

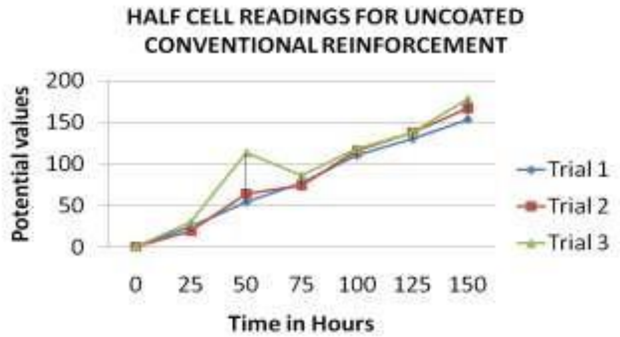


Figure 11. Half-cell reading for uncoated conventional reinforcement

Table 6. Half-cell reading for coated conventional reinforcement

| Time Intervals | M 25 | | |
|---|---|---|---|
| | Trial I | | Trial I |
| 0 | - | - | - |
| 25 | 178 | 180 | 196 |
| 50 | 209 | 210 | 218 |
| 75 | 210 | 220 | 222 |
| 100 | 233 | 249 | 240 |
| 125 | 259 | 264 | 289 |
| 150 | 270 | 281 | 291 |

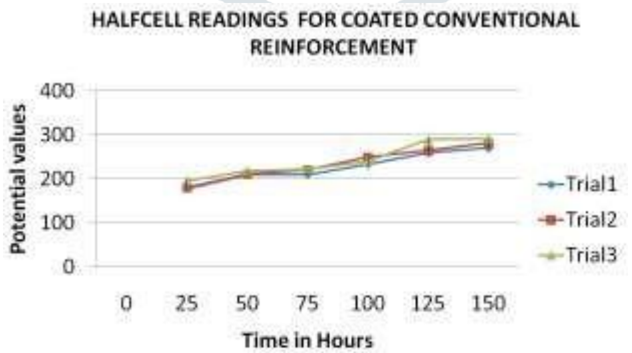


Figure 12. Half-cell reading for coated conventional reinforcement

Table 7. Half-cell reading for uncoated reinforcement with fibre

| Time Intervals | M 25 | | |
|---|---|---|---|
| | Trial I | Trial II | Trial III |
| 0 | - | - | - |
| 25 | 192 | 170 | 170 |
| 50 | 160 | 155 | 153 |
| 75 | 249 | 263 | 235 |
| 100 | 267 | 264 | 263 |
| 125 | 317 | 332 | 312 |
| 150 | 330 | 344 | 347 |

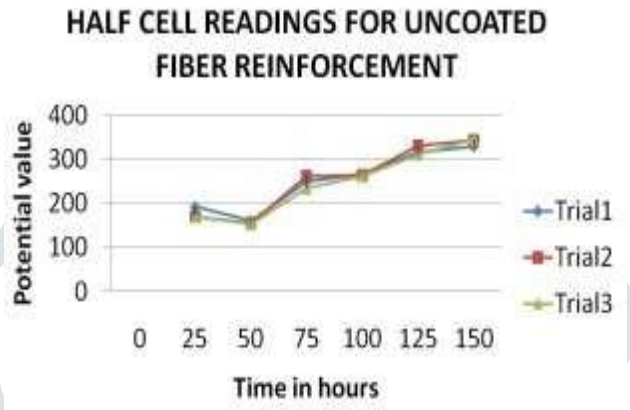


Figure 13. Half-cell measurement reading for uncoated reinforcement with fibre

From the Fig 13, it shows an increase in the potential value in the trial III, with increasing time interval.

Table 8. Half-cell reading for coated reinforcement with fibre

| Time Intervals | M 25 | | |
|---|---|---|---|
| | Trial I | Trial II | Trial III |
| 0 | - | - | - |
| 25 | 2 | 10 | 14 |
| 50 | 19 | 37 | 21 |
| 75 | 49 | 54 | 60 |
| 100 | 79 | 83 | 94 |
| 125 | 100 | 102 | 103 |
| 150 | 131 | 168 | 154 |

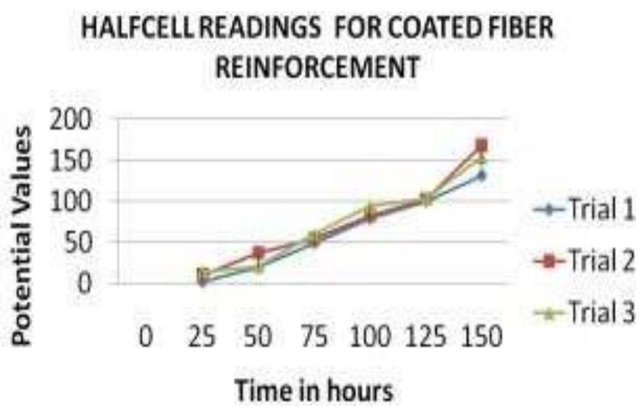


Figure 14. Half-cell reading for coated reinforcement with fiber

## VI.CONCLUSION

In the present work an attempt was made to study the effectiveness of corrosion protection of rebar using coating materials and fibre concrete in M 25 grade of concrete. The efficiency of the coating material was compared with that of the uncoated rebar. The weight loss method was used to determine the percentage of corrosion. The corrosion of the concrete is taken as the end point of the corrosion process. The rate of corrosion was monitored using the saturated calomel as the references electrodes alternate measurement. The rod diameter spacing and cover are kept over constant.

- The coated rebar with fibre is preventing more corrosion than other specimens.
- Fibre gives 40% better strength than conventional concrete

The coated bars of reinforcement are less corroded than the uncoated bars of reinforcement. The corrosion protective quality of R.C. slabs in M 25 grade concrete with fibre seems to be good with protective coating on rebar.

## REFERENCES

[1] Sagar Gadhiya, Patel T N and Dinesh Shah(2015) "Parametric study on flexural strength on ECC 2015 ijscer vol:4 no:5

[2] S.Z. Qian, J. Zhou, E. Schlangen"Influence of curing condition and pre cracking time on the self healing behaviour of Engineered Cementitious Composites" Journal of Cement & Concrete Composites 32 (2010) pp. 686–693.

[3] Jian Zhou, Shunzhi Qian, Guang Ye, Oguzhan Copuroglu, Klaas van Breugel , Victor C. Li," Improved fibre distribution and mechanical properties of engineered cementitious composites by adjusting the mixing sequence,"Jounal of Cement & Concrete Composites" 34(2012)pp.342–348.

[4] Seminar report on on "Bendable concrete"presented by Chitari Nagesh Babasahebi m.tech. in structural engineering Basaveshwar Engineering College Bagalkot

[5] Li VC, Kanda T. "Engineered cementitious composites for structural applications". ASCE J Mater Civil Eng 1998.

[6] Bensaid Boulekbache, Mostefa Hamrat, Mohamed Chemrouk, Sofiane Amziane, "Influence of yield stress and compressive strength on direct shear behaviour of steel fibre- reinforced concrete", Journal of Construction and Building Materials 27 (2012) pp.6– 1