"EXPERIMENTAL INVESTIGATION ON CORROSION IDENTIFYING AND ENHANCEMENT OF EXISTING CONCRETE STRUCTURES"

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ABSTRACT

Corrosion on structure is one of the biggest challenges faced by the civil engineers. Since repairing at rehabilitation requires costly treatments without considering corrosion damages on the structures. Identifying the corrosion on the concrete structure requires more research to solve effectively. A majority of concrete structure is shows signs of degradation due to the corrosion of the reinforcement in the presence of chlorides. In some cases, the degradation is visible with in few years of construction completion. Despite the fact that the concrete structure is particularly suffer premature degradation due to corrosion, due to poor construction quality as a result of poor workmanship. Inadequate standards based on prescriptive measures and poor design as a result of insufficient information with regards the parameters that influence the degradation process. While standards are gradually improving, with the tendency to become performance based in future, much information is needed to assist the designer in the decision making process.

A durability model for the reinforced corrosion, based on the Half-Cell Potential Meter Apparatus with different environment. A model is prepared and then the model in tested by immersing in tap water with three known P_H value ($P_{H\ 7.5}$, $P_{H\ 9}$, $P_{H\ 13}$,) The corrosive effects of tap water, after a certain period of time is calculated by the model is taken out and the by measuring corrosive factors, then these factors are Compared with the actual structures. After this comparison to enhance the life time of structures, chemical coating is applied to concrete models and the effects are studied. After such studies the most successful chemical coating can be applied to the concrete models, which in turn increases the life time of buildings. This project would propose the effective and cost saving chemical coating.

1. INTRODUCTION

The main and frequent cause of corrosion of reinforced concrete structure is chloride attack and carbonation. Chloride come from several sources. They can be cast in concrete but often they can diffuse in to concrete as a result of salt water wetting. All corrosion risk system enable the user to determine the depth of critical condition in the concrete. Installed above the reinforcement, the system can be used to estimate, when reinforcement will star to corrode. Two corrosion risks categories were addressed.

Primary Risk

Degradation of reinforced concrete sub structures, due to the ingress of saline ground water leading to built up of chlorides eventually leading corrosion of the steel reinforcement.

Secondary risk

Degradation of above ground concrete due to accumulation of air blown chloride rich dust depositing in concrete surfaces.

The corrosion Mechanisms involved in the carbonation, chloride attack and corrosion of reinforcement have been studied by many researchers (Bernander and Oberg 1966, Nurnberger

1984, Jones et al 1996) as is well known, the corrosive effect of carbonation is based on the decreasing trend of alkalinity of pore liquid in concrete and the resulting depassivation of steel, making it able to corrode. The significant influence of various factors like cement type, w/c ratio, mineral additives as well as condition of concrete preparation and site have been reported in many studies.

The aim of my project is to prepare a concrete models to find out the corrosive effects of ordinary tap water and to determine this the models are immersed in the tap water and after certain period it is taken out.

The models are measured to the rate of corrosion and then it is compared with concrete structures. The chemical coatings are applied to the concrete models and the most effective chemical coating is them applied to concrete structure.

2. Literature Review

Background

Concrete structures generally make up a significant and important part of the national infrastructure. It is estimated that within Europe structures represent approximately 50% of the national wealth of most countries (Long et al 2001). Both the condition and performance of all these structures are essential for the productivity of the society.

In most EU countries approximately 50% of the expenditures in the construction industry are spent on repair, maintenance and remediation of existing structures. In future, these expenses are expected to increase even more. A large proportion of these expenses are due to problems related to lack of durability of concrete structures (Lindvall 2001). The growing number of deteriorating concrete structures, not only affects the productivity of the society, but has also a great impact on resources, environment and human safety. The operation, maintenance and repair of concrete structures are consuming ever more energy and resources while heavily burdening the environment with the large quantities of waste produced. Thus, the poor durability and premature end of the service life of concrete structures do not only represent technical and economical problems, but also a poor utilization of natural resources and therefore an environmental and ecological problem (Gjorv 2001).

In recent years, an extensive amount of research work has been carried out in order to better understand and control several of the most important deteriorating mechanisms such as alkali aggregate reactions, freezing and thawing and corrosion of embedded steel. In particular, much work has been carried out on corrosion of embedded steel, which represents the greatest threat both to the safety and economy of the structures. Never before so much basic information and knowledge about concrete durability has been available. The great challenge to the professional society is, therefore, to utilize and transform more of this existing knowledge into good and appropriate engineering practice (Gjorv 2002).

The traditional methods used for durability design are usually based on deem-to-satisfy rules, where sufficient durability of a concrete structure is secured with prescriptive requirements. Examples of prescriptive requirements are the usage of specified water/binder ratios, minimum concrete covers and minimum cement content. With the deem-to-satisfy methods it is expected that the concrete structure will achieve a long but not specified service life.

The problems related to durability and execution of work has been underestimated for many years. Main emphasis has been given to mechanical properties and structural capacity, while durability design, construction quality and life cycle management have been neglected. Seldom do the owners of the concrete structures come up with special requirements for durability and long-term performance of their structures (Gjorv 2002).

Usually the performance criteria are defined as limit states. The limit state is the border that separates desired states from the undesired or adverse states in situations, acceptable to the owner, which a structure may be subjected to during its lifetime (DuraCrete 1999). A difference is made between the ultimate limit state, where the safety of the structure is considered (for example the risk of collapse), and the serviceability limit state, where the functionality of the structure is considered (for example the limitation of crack widths.

Corrosion of steel reinforcement can seriously compromise the service life of reinforced concrete structures. Hence, service life prediction and enhancement of concrete structures under corrosion attack are of significant importance. As a result, numerical methods that can reliably predict the service life of concrete structures have attracted increasing attention. In this, the first of two companion papers, a simple and significantly improved inverse relation relating the current density with potential for the cathodic reaction is proposed. This enables the current densities to be determined accurately from the measured potentials. Equally importantly, the proposed inverse relation also enables the efficient and straight-forward nonlinear algorithm for modeling of steel corrosion in concrete structures to be developed. Such an algorithm is presented in the companion paper of this.

Keywords: Corrosion, Concrete, Numerical modeling, Inverse relation, Cathodic reaction

Corrosion of steel:

Corrosion of steel reinforcement is a well-known and well-documented phenomenon, and is considered the most prevalent form of deterioration of reinforced concrete structures [1, 2]. Initially, due to the highly alkaline nature of the concrete, a passive protective oxide film is formed on the

surface of the steel reinforcement, effectively preventing the steel surface from being corroded. The passive protection layer, however, may be seriously compromised when the chemical composition of the pore solution is altered by carbonation or chloride contamination of the concrete cover. As a consequence, corrosion begins, resulting in a reduction in steel cross-sectional area, cracking, and spalling as well as loss in bond between steel and concrete.

Modes of concrete deterioration

Deterioration is any adverse change of normal, mechanical, physical, and chemical properties either in the surface or in the body of concrete, generally due to the disintegration of its components (Anonymous 1987, Masters 1987, Cady 1990, Higgins 1981) The phenomenon which induces such distress may be associated with one of the phases (e.g. design, construction, or service). The effects of deterioration may or may not be manifested visually. There are three basic visual symptoms of distress in a concrete structure:

- Cracking
- Spalling and
- Disintegration.

In addition to the deterioration of concrete, the breakdown of other auxiliary materials, such as sealants, coatings, membranes, which form the complex assembly of a structure, should also be considered. Polymeric products often interact with other materials with which they are in contact to form compounds which are devoid of the characteristics of the original.

3. PROPOSED CONCRETE MODELS FOR DURABILITY

ANALYSIS

To find out the rate of corrosion, first I have prepared 7 Nos. of concrete cube models. The size of the cube model was 150 x 150 x 150mm In M35 concrete grade that have mixed the design and prepared the concrete. Here have fixed 16mm dia steel at the centre of the cube and inserted in if like wise the M35 concrete grade of the mixed proportion, also prepared concrete and 7 numbers of cylindrical concrete model.

The above models were inserted in the centre of 16mm bar. Then I have bring out the cylindrical concrete model and concrete cube model differently and cured it in the water content of PH values for nearly 28 days. After 28 days I have measured the corrosion rate of steel rod in cylindrical models and cube models.

To measure the rate of corrosion in the steel rod I had used the apparatus of Half cell potential meter.

Also, I have submitted that the detail of the corrosion rate with inclusion of coating, the corrosion rate would be his given as follows, from which, the durability would be increased like with the corrosion rate would be reduced.

HALF –CELL POTENTIAL METER TESTING OF CONCRETE MODELS

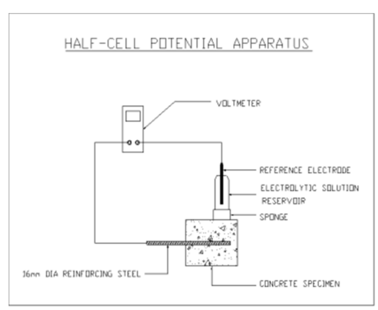
Half-cell potentials as an indication of corrosion potential has developed from the success of corrosion surveys, as a result ,potential surveys are now commonly conducted on bridges, garages, water tanks, pre-cast concrete tunnel liners, and many other structures. The Half-cell potential measurements provide a classification of the corrosion activity of the steel and indicate locations where the steel is potentially corroding, although potentials cannot be used to estimate the rate of corrosion of the steel or the steel or the condition of the concrete

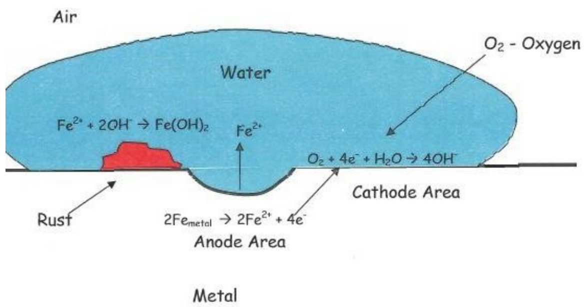
A half-cell potential measurement apparatus consists of a voltmeter with one lead connected to a reference electrode, normally a copper, copper-sulfate ($Cu/CuSO_4$) electrode, placed on the surface of the concrete and a second lead connecting the voltmeter to the reinforcing steel. Current passes from the reference electrode to the concrete surface through a sponge soaked with an electrolytic solution. The objective of the instrumentation is to measure the voltage, or potential setup, the reference electrode behaves as the cathode, as copper is higher in the galvanic series than steel.

Through the circuit created, the potential difference is measured. With the reference electrode acting as the cathodes and being connected to the positive terminal of the voltmeter, measured half-cell potentials have a negative value. A half-cell potential measurements results from the multiplication of the reinforcement corrosion potential by the ration of there internal resistance of the voltmeter to the sum of the internal resistance of the voltmeter and the resistance of the concrete. A schematic of the test circuit is shown in figure.

VARIOUS METHODS OF TO FIND OUT THE RATE OF

HALF –CELL POTENTIAL APPARATUS





PROCEDURE FOR WATER TEST

PROCEDURE FOR pH MEASUREMENT

Sample 1 is taken in a clear beaker. The electrode is cleaned in distilled water and dipped into the solution. The pH meter is connected to the source of electricity and switched on. The reading in the display gives the pH of the solution. Similarly the pH values of the remaining samples are directly measured by using the pH meter.

Sl No.	Sample	pH Value
1	Sample 1	8.5
2	Sample 2	9.5
3	Sample 3	12

TOTAL HARDNESS (EDTA METHOD)

Procedure:

20ml water sample is taken in a conical flask. About 5 ml of ammonia buffer solution and a pinch of Erichrome black-T indicator are added. The contents in the conical flask change into wine red colour. This is titrated against 0.01M EDTA solution. The end point in the change of colour from wine red to steel blue. The volume of EDTA consumed in noted.

Calculation

Volume of EDTA = V ml

Volume of hard water = 20 ml

1 ml of 0.01M EDTA = 1mg of $CaCo_3$

V ml of 0.01M EDTA = V mg of $CaCo_3$

20ml of water contains = V mg of $CaCo_3$

20gm of water contains = $V \times 10^{-3}$ gm of CaCo3

10^6 gm of water contains = $\frac{V \times 10^{-3} \times 10^6}{20}$

Total hardness of water = 50 x V ppm

Sample – I

Sample – I V = 2.8ml (Titration value)

Total hardness of water sample – 1 = 50 x 2.8 = 140 ppm

Sample – II

Titration Value V = 14ml

Total hardness of water sample – II = 50 x V ppm = 50 x 14 = 700 ppm

Sample – III

Titration Value V = 18ml

Total hardness of water sample – III = 50 x V ppm = 50 x 18 = 900 ppm

ALKALINITY

Pipette out 100ml of the water sample in a clean titration flask (conical flask). Add to it 2 to 3 drops of phenolphthalein indicator. Run in N / 50 H2 So4 (from a burette), till the pink colour is just discharged. Then to the same solution, add 2 (or) 3 drops of methyl orange. Continue the titration, till the pink colour reapers.

Calculation

$$\text{Alkalinity} = \frac{(V_1 + V_2) \times 50 \times 1{,}000{,}000}{50 \times 100 \times 1000}$$

Sample : I Nil = $10 (V_1 + V_2)$ ppm

Sample : II

Alkalinity (OH) = $10 (V_1+V_2)$ ppm

V_1 = 10 ml

V_2 = 10 ml

Alkalinity = 10 (10 + 10)

= 10 x 20

Alkalinity = 200 ppm

CHLORIDE

Procedure :

Take about 10ml of 10% KI solution in a stoppered 250 ml conical flask. Add to it 50ml of water sample. holding the point of the pipette just above the iodide solution. Put on the stopper and shake the flask vigorously. Remove the stopper and wash the adhering solution into flask, with about 5-10 ml of distilled water. Then, titrate the solution against N/50 sodium thiosulphate solution, using strarch as final indicator. The end point is the colour from deep – blue to just colourless.

Water Quality Parameters

Sl.	Parameters tested	Location of water Sample			Standard-value for potable water	
		Location-1	Location-2	Location-3	WHO	ICMR
1.	pH	8.5	9.5	12	8.5	8.5
2.	TDS	250 ppm	560 ppm	950 ppm	500 ppm	500 ppm
3.	Total hardness	140 ppm	700 ppm	900 ppm	350 ppm	350 ppm
4.	Alkalinity					
	OH^-	Nill	200 ppm	450 ppm	----	20 ppm
	CO_3^{2-}	15 ppm	Nil	Nil	----	20 ppm
	HCO3	220 ppm	300 ppm	350 ppm	----	20 ppm
5	Chloride	125 ppm	550 ppm	700 ppm	250 ppm	250 ppm
6	DO	7.5 ppm	8.9 ppm	9.0 ppm		

POTENTIAL MEASUREMENT OF UNCOATED ROD

RATE OF CORROSION

PH – 8.5

PERIOD – 28 DAYS

Model	Cylindrical Model – 1	Cube Model
Model 1	-0.35	-0.35
Model 2	-0.35	-0.34
Model 3	-0.36	-0.36

PH – 9.5

PERIOD – 28 DAYS

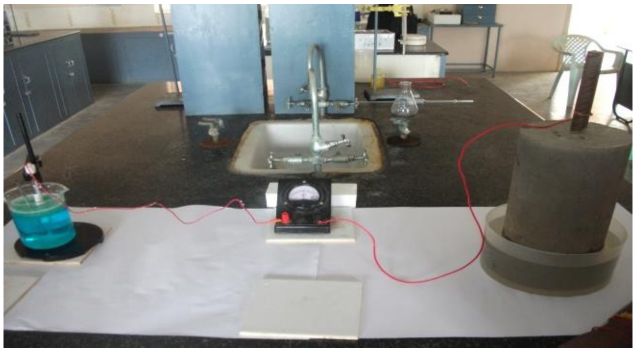
Model	Cylindrical Model – 1	Cube Model
Model 1	-0.42	-0.39
Model 2	-0.44	-0.42
Model 3	-0.43	-0.41

PH –12

PERIOD – 28 DAYS

Model	Cylindrical Model – 1	Cube Model
Model 1	-0.54	-0.50
Model 2	-0.55	-0.52
Model 3	-0.53	-0.54

PREPARATION OF CYLINDRICAL CONCRETE MODEL

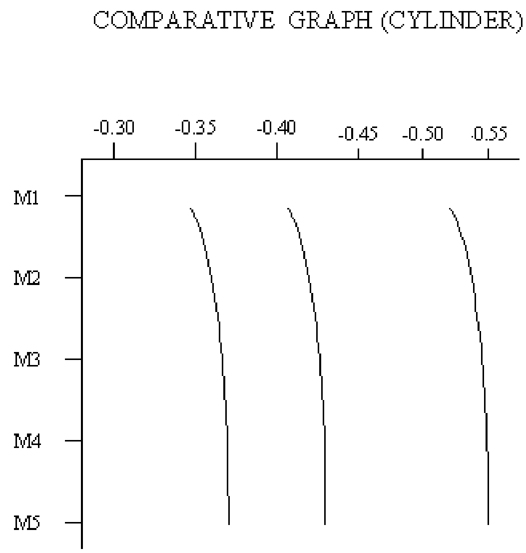


Effective zinc Coating

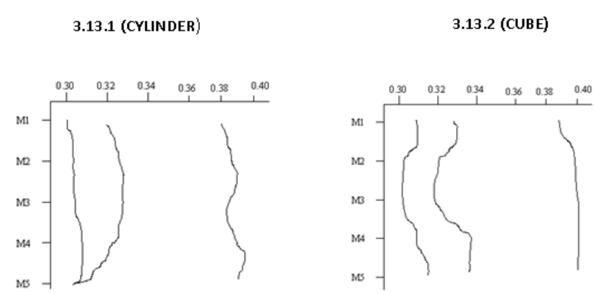
Concrete cube with effective coating

POTENTIAL MEASUREMENT OF COATED ROD

RATE OF CORROSION (+ve Potential)



3.13 COMPARISON GRAPH (WITH COATING)



Depends upon the pH corrosion rate decreases

4. ADDITIONAL METHOD

PROPOSED CONCRETE MODELS INSERTING 16mm DIA ROD @ CORNERS

To find out the rate of corrosion, first I have prepared three numbers of concrete cube models. The size of the cube model was 150 x 150 x 150mm in M_{35} grade concrete mix design and prepared the concrete. The cube casting with fixed the 16mm diameter steel rod at the corners of the cube and also prepared the concrete cube casting with inserted the 16mm dia rod @ corners and centre of the cube.

The above concrete cube models are curing in different environment [various P_H values like 8.5, 9.5

and 12.0] nearly 28 days. After 28 days curing, I have measured the rate of corrosion by half-cell potential meter apparatus.

Also, I have prepared above format of cube models with applying the effective zinc coating. The models are curing in different environment @ 28 days. After 28 days curing to find out the rate of corrosion.

4.2 PREPARATION OF CUBE MODELS

RATE OF CORROSION

CUBE CASTING WITHOUT ZINC COATING

LOCATION	**CUBE MODELS INSERTING RODS @ CORNERS**			
	ROD – 1	**ROD – 2**	**ROD – 3**	**ROD – 4**
P_H 8.5	-0.30	-0.30	-0.31	-0.32
P_H 9.5	-0.40	-0.40	-0.40	-0.42
P_H 12.0	-0.49	-0.49	-0.50	-0.50

LOCATION	**CUBE MODELS INSERTING RODS @ CORNERS AND CENTRE**				
	ROD – 1	**ROD – 2**	**ROD – 3**	**ROD - 4**	**ROD-5 (CENTRE)**
P_H 8.5	-0.30	-0.30	-0.31	-0.32	-0.30
P_H 9.5	-0.40	-0.40	-0.40	-0.42	-0.40
P_H 12.0	-0.49	-0.49	-0.50	-0.50	-0.52

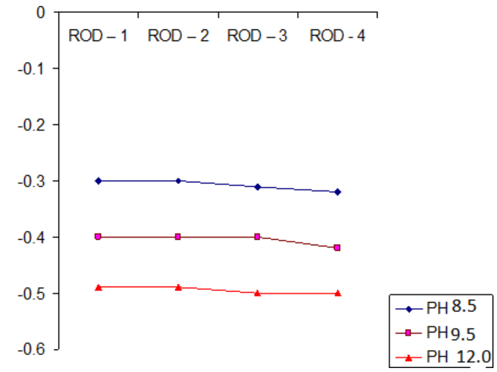
POTENTIAL MEASUREMENT TESTING

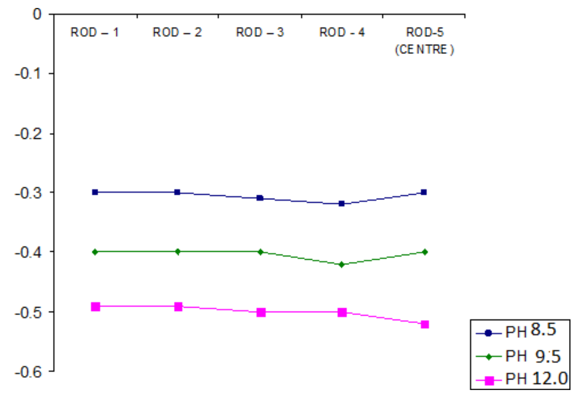
PREPARATION OF CUBE MODELS WITH ZINC COATING

RATE OF CORROSION

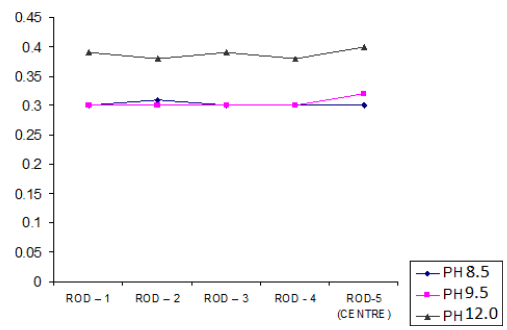
CUBE CASTING WITH ZINC COATING

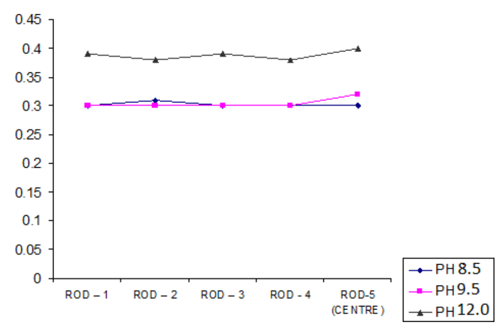
LOCATION	CUBE MODELS INSERTING RODS @ CORNERS			
	ROD – 1	ROD – 2	ROD – 3	ROD – 4
P_H 8.5	0.30	0.31	0.30	0.30
P_H 9.5	0.30	0.30	0.30	0.30
P_H 12.0	0.39	0.38	0.39	0.39





LOCATION	CUBE MODELS INSERTING RODS @ CORNERS AND CENTRE				
	ROD – 1	ROD – 2	ROD – 3	ROD - 4	ROD-5 (CENTRE)
P_H 8.5	0.30	0.31	0.30	0.30	0.30
P_H 9.5	0.30	0.30	0.30	0.30	0.32
P_H 12.0	0.39	0.38	0.39	0.38	0.40





5. CONCLUSION

My project aim is to compare and analysis also correction to be made in the concrete models. In the site, all the corrosion data to be collected, After such studies the most effective successful chemical coating can be applied to the concrete structures which is applicable to increase the life time of buildings, also an effective cost saving and enhancement of life time of the concrete structures are achieved.

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