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Effect of rebar coating in the prevention of corrosion in RC structure

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ABSTRACT

Corrosion of the reinforcement in concrete structures had been realised to be at serious problem world wide in the 60s & 70s & the amount of damages still increased considerably in the 80s. Corrosion in steel reinforcement is one of the most significant factors in the deterioration of Reinforced Concrete Structures Rebars Corrosion carbonation of Concrete & Chloride Attack Affects almost 50% The Durability of concrete structures. Earlier studies Indicated the Reinforced Concrete structures Remain durable for the whole of their design life, Approximately more than 60 years, Even maintenance free. The purpose of this study is to evaluate and compare the relative merits of the two coating systems for reinforcing bars in concrete. Also this study helps to know the nature and characteristics of both epoxy coated and Zinc Coated Steel for use as reinforcement in concrete. Also presented is an overview of the results from recent experimental work on the comparative corrosion behavior of uncoated Steel, epoxy coated steel, and Zinc Coated Steel in concrete.

Keywords- *Rebar, Corrosion, Epoxy ,Zinc, Reinforcing Steel*

1. INTRODUCTION

1.1 General

The structures built before the innovation of modern cement used the lime as binding material & stone, bricks or timber were used for making structural element. Now a days it is assumed that the concrete made by using today's modern cement will have a useful life more than 100years similarly it is assumed that the steel will have a useful life more than concrete if protected & proper metallurgical composition designed.

Today the major problem currently confronting the construction industry all over the globe is 'deterioration of RCC structures'. This problem created almost a crisis like situation & as put the engineering fraternity on red alert. The present average life of RCC structures in India in coastal areas is about 30-60 years.

1.2 Corrosion in rienforced concrete

Corrosion is a natural process that occurs when the steel rebar within reinforced concrete structures rusts. In scientific terms, concrete corrosion is defined as the "destruction of metal by chemical, electrochemical, and electrolytic reactions within its environment. The annual cost of corrosion in India is around Rs.600 cr. The loss due to corrosion include the cost of repair or replacement of the corroded component or equipments. By making proper use of existing corroded materials and techniques for corrosion prevention, about 25% of the estimated amount (Rs. 150 crores in India) can be saved.

Strength of steel has been far much better than concrete yet later is the most widely used engineering material, this can be explained with three main reasons: One of the main reason is the excellent resistance of concrete for water which makes it a superior material than wood or steel for structural purposes. The second reason is that the concrete can be formed into different structural elements easily. Its easy availability and cost efficiency is the third and most important reason behind the popularity of concrete . Reinforcement of concrete with steel is done to strengthen the structural element in tension as concrete is weak in it, but structures do fail as a result of corrosion attack on steel . It has become a serious, widespread problem worldwide, with costly repairs now in billions of dollars annually. In addition, the numerous intangible losses such as the energy needed to manufacture replacements of corroded objects. The steel corrosion in reinforced concrete reduces its durability and can even result in failure of the structure.

Following are some facts about corrosion of steel, In general

1. Internationally, 1 tonne of steel turns into rust every 90 seconds

2. The energy required to make 1 tonne of steel is approximately equal to the energy an average family consumes over 3 months.
3. To make 1 tonne of steel, around 2.9 tonnes of CO_2 equivalent of Green House Gases are pumped into the atmosphere.
4. Of every tonne of steel from the world's production, approximately 40% is required to replace rusted steel.

1.3 Corrosion Process

Corrosion in concrete is induced by the generation of the electrochemical potentials in following ways:

1. When two different metals are present in concrete, such assteel rebars, aluminium conduit pipes, or when significant variation exist in surface characteristics of the steel, formation of composition cell can occur.

2. Concentration cells may be formed near reinforcing steel because of the differences in the concentration of dissolved ions, such as alkalies and chlorides.

The following reactions occur at anode and cathode.

$$\text{Anode: } Fe \rightarrow Fe^{2+} + 2e^-$$

(Metallic iron)

$$FeO.(H_2O)x$$

(Rust)

$$\text{Cathode: } \tfrac{1}{2}O_2 + H_2O + 2e^- \rightarrow 2OH^-$$

Some parameters are essential to initiate corrosion. Presence of oxygen, humidity (electrolyte) are the two important parameters without which corrosion is not possible. The rate of corrosion is slow if the amount of water or oxygen is limited. Presence of humidity, moisture and oxygen acts as catalyst for corrosion to occur, forming more OH thereby producing more rust component Fe(OH)-

Following reactions represent the formation of the rust after the iron dissolution occurs at the anodic sites in the reinforcement

$$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2 \text{ (Ferrous Hydroxide)}$$

$$4Fe(OH)_2 + 2H_2O + O_2 \rightarrow 4Fe(OH)_3 \text{ (Ferric Hydroxide)}$$

$$2Fe(OH)_3 \rightarrow 2H_2O + Fe_2O_3 \cdot H_2O \text{ (Rust)}$$

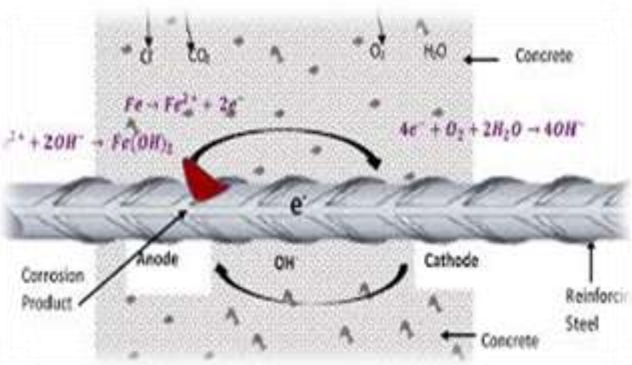

Figure1: Electrochemical process of corrosion of steel in concrete

1.4 Causes of Corrsion In Rcc

During the service life, the embedded steel gets corroded due to many reasons. The primary reasons are presence of moisture and lack of adequate concrete cover to steel. There are other reasons which also causes corrosion of reinforcement steel in concrete. i.e. the process of carbonation, electrolysis, alkali-aggregate reaction in concrete. Steel reinforcements also gets corroded due to the use of calcium chloride ($CaCl_2$) as the accelerator, outside and inside moisture presence in concrete, the presence of chemicals like soluble sulphate in water. Sometimes, impurities like inorganic compounds, sulphates and chlorides present in mixing or curing water also causes the corrosion in concrete.

1.5 *Rebar Coatings*

Epoxy-Coated Reinforcing Bars: Epoxy coating of reinforcement has been widely used since the mid-1970's to combat corrosion, particularly in salt contaminated concrete such as highway bridge decks, marine structures, etc. Epoxy coating provides good corrosion protection to steel and the coating is not consumed in performing its function. The coating is essentially inert and highly resistant to both the alkaline environment of concrete and the penetration of chlorides. The barrier protection it affords to steel is due to the complete isolation of the steel from the environment. The epoxy coating itself does not corrode.

Figure 2: Epoxy Coated Reinforcing

The corrosion behavior of epoxy-coated bars depends mainly on the following factors:
1. Chloride does not penetrate the epoxy coating, but enters through a break in the coating and travels along the steel surface
2. Corrosion performance of epoxy-coated bars is related to the holiday count and electrical resistance qualities of the coating. Electrical resistance depends upon proper film thickness, good surface preparation and low holiday counts.
3. Excellent corrosion performance is based upon final average current densities less than 0.01 mA/ft2, intermediate corrosion performance is based upon corrosion current density between 0.01 and 0.10 mA/ft2, and poor corrosion performance is based upon current densities greater than 0.10 mA/ft2

Zinc Coated Reinforcing Bars: Zinc coating on iron and steel products has been used over many years for corrosion protection of exposed structural steel and other consumer products. It has been used over 60 years for corrosion protection of steel reinforcement. Zinc coating provides barrier protection by isolating the steel from the local environment. It has higher chloride tolerance than black steel and it takes longer time to depassivate zinc than black steel.

In addition to this, galvanized coating provides an extra measure of corrosion protection because of its inherent sacrificial nature. Zinc coatings passivate very quickly when exposed to fresh concrete, which enhances the long-term corrosion protection of the galvanized reinforcements during years of service. The initial passivation of a zinc coating, when embedded in concrete, occurs within hours and is affected by the chemistry of the surface layer.

Figure 3: Zinc Coated Reinforcement bars

2.MATERIAL AND PROPERTIES

Cement

Cement Ordinary Portland Cement (OPC) of Grade 43 grade confirming to IS 5112(2013), has been used in the present study. The cement considered has been tested to obtain specific gravity, normal consistency, setting times and compressive strengths as per relevant Indian standard code of practices Table present the results of the tests conducted on cement. The results have been compared with standard values and found that all the test results comply with the respective specifications

2.1 Fine Aggregate

The Fine aggregates are used for the mixes The material has been tested as per Indian Standard Code of Practices and results have been found satisfying the relevant Indian Standard Specifications. The physical properties of fine aggregate are presented.

2.2 Coarse Aggrgate

Coarse aggregate is considered to be the strongest and least porous component of concrete. It should be also a chemically stable material. The strength of concrete cannot exceed that of the bulk of aggregate contained therein. Locally available crushed granite aggregate of 20mm down size conforming to Indian Standard Specification was used as coarse aggregate for the present work. The physical properties of coarse aggregate are tabulated.

2.3 *Water*

The amount of water should theoretically be enough for complete hydration of cement and should not contain any harmful materials in it. Potable water has been used for making concrete in the present study.

2.4 Preparation of mould

The moulds were of steel rectangular shape 150mm x 150 mm x 650 mm with a diameter hole of 12 mm @ the centre of breadth sides. Prior to coating preparation, the Reinforcement were polished according to ISO 8501-1:1988 by using copper brush and degreased with thinner to clean the surfaces from oil content. The samples were stored in the desiccators before coating.

2.5 Coating Process

In this study, the paint has been prepared by using zinc rich primer/thinner/hardener & Epoxy Coating composition with the manufacturer recommended mixing ratio. The mixture was applied to the mild steel using compressed air sprayer. The coating thickness was considered as 50 μm, 150 μm and 250 μm. After coated, the sample was completely dried in an oven; a scratch mark is applied on the surfaces by using Scratch, Adhesion and Mar (S.A.M) tester.

2.6 Casting & curing of specimen

The Cement & Aggregate are mixed thoroughly up to the proportion calculated. Then the calculated (volume) amount. of water is to be added to the mixture & Mix well to get a homogeneous mix. Then place the Concrete inside the mould. Where the Reber is already provided in the centere the mould longitudinaly. Concrete will be poured inside the mould & Compacted. by tamping using tamping rod. After casting of specimen, it will be kept for 24 hours or 1 day to be hard, then specimen will be removed from the mould and kept it for curing. Generally curing is done to get maximum strength of that material according to the days it cured. Hence we cured the specimen for 28 days.

Figure 4 : Casting & Curing of Specimen

3. MATERIAL TEST RESULTS

Table 1: Physical Properties of Cement

Sl no	Properties	Results	As per is:8112
1	Standard Consistency	32%	-
2	Fineness of Cement	7.17%	<10% 225M2/KG min
3	Intial Setting	40min	➢ 0Min
4	Specifice Gravity	3.02	-

Table 2: Physical Properties of Fine Aggregates

Sl no	Properties	Fine aggregates
1	Specific Gravity	2.67
2	Percentage of Bulking	5.15%
3	Grading	Zone 2

Table 3: Physical Properties of Coarse Aggregates

Sl no	Properties	Results
1	Specific Gravity	5.15
2	Bulk Density (loose)	1.40g/cc
3	Bulk Density	1.55g/cc

4. RESULTS AND DISCUSSION

Half Cell Potential Test

The half-cell potential measurement is undertaken generally as per ASTM C876. The probability of corrosion rate measurements are in Table 4 to obtain electrochemical condition of the specimens and to enable a cleareinterpretation of test results.

Figure 5: Half Cell Potential Test

Table 4: Results of Half Cell potential Test as per ASTM C876

Sl .no	Coating Type	Measured Potential Values in (mv)	Probability of Corrosion
1	Uncoated Specimen	-386	High Probability of Corrosion (Advanced Stage)
2	Coated by Nitrozinc Primer	-240	Uncertainity of Corrosion (Moderate Stage)
3	Coated by Epoxy Primer	-255	Uncertainity of Corrosion (Moderate Stage)

Flexural Strength Test

Flexural test evaluates the tensile strength of concrete indirectly. It tests the ability of unreinforced concrete beam or slab to withstand failure in bending.The results of flexural test on concrete expressed as a modulus of rupture which denotes as (MR) in MPa.

Table 5: Results of Flexural Strength Test

Sl no	Particulars	Un coated Specimen	Coated Specimen	
			Epoxy Coated	Zinc Coated
1	Failure Load (KN)	58.653	73.823	74.143
2	Mid Span Deflection (mm)	7.343	5.732	5.692
3	Bar Dia (mm)	12	12	12
4	Yeild Strength (Mpa)	415	415	415
5	Ultimate Tensile Strength (Mpa)	551.353	623.95	624.252
6	Elongnation (%)	15.943	20.616	20.974

5. CONCLUSION

1.Neither epoxy coating nor Zinc Coating can assure complete prevention of corrosion of reinforcement in concrete over long periods of exposure. However, coated reinforcement is expected to have longer life than Uncoated steel reinforcement under equivalent circumstances.

2.Therefore, reinforced concrete components utilizing coated reinforcing bars are expected to have a longer life and lower life-cycle costs than those with uncoated reinforcing.

3.When in Coated specimen, when compared each other, nitrozinc coated specimen has slightly high tensile strength, failure load, mid span deflection & Elognation percentage Compared to epoxy coated specimen

4.So, It concluded that nitrozinc primer is little bit more effective than the epoxy primer. However, The chemical coatings are adopted according to site condition, environmental condition material to be used for construction

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