AN EXPERIMENTAL INVESTIGATION OF TMT BARS USING EPOXY RESINS AND CALCIUM NITRITE CEMENT SLURRY

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Abstract -*Concrete is the most widely used building material in the world due to its low cost and durability. Corrosion of steel in concrete is one of the major causes of deterioration of concrete structure. This Project focuses on the comparative investigation in prevention of corrosion on reinforcement bars by means of coating process using epoxy resins and calcium Nitrite cement slurry. This process will be evaluated by cathodic protection test and chemical resistance test. The property of the steel coating will be examined by tensile test, Pullout test.*

***Key Words*:Epoxy coating, Calcium nitrite, TMT Bars, M Sand**

1. INTRODUCTION

1.1. General

Corrosion of steel in concrete is highly probable in marine and urban areas which take places due to chloride ions and carbonation respectively. The expected service life of a structure can be significantly reduced when chloride penetrates the concrete and reaches to the level of the steel reinforcement. Once corrosion is induced and reinforcing steel has cracked the concrete, more chloride penetrates to attack the reinforcement and deterioration of the structure take places at faster rate. The deterioration of reinforced concrete structures due to corrosion of the reinforcing steel is of concern world-wide.

The Corrosion of the steel in concrete can be prevented by various methods such as coatings to steel, coatings to concrete, cathodic protection, and addition of super plasticizers, electrochemical removal of chloride, desalination, electrochemical re-alkalization and by corrosion inhibiting admixtures. Concrete structures in aggressive environments such as coastal and industrial areas are subjected to chloride attack. In the above methods coatings to steel is sound to be economic and ease of application.

Epoxy phenolic – IPN coated reinforcing bars have emerged as available and cost-effective corrosion-system for reinforced concrete structures. According to the original research. The epoxy phenolic – IPN system was developed for protection of steel structural and now moisture and chlorides from coming in contact with the bars. Epoxy coating acts as an electrochemical corrosion barrier which electrically isolated the bars by reducing the flow of corrosion current.

Corrosion may affect residual capacity through several mechanisms, including loss of bar section, loss of concrete section as a result longitudinal cracking and spalling, and a reduction in the interaction, or bond, between reinforcement and concrete. This study focuses on the comparative investigation in prevention of such corrosion on reinforcement bars by means of coating process using epoxy and Cement Slurry.

Pitting attack is a more insidious form of attack for two reasons. First, the localized nature of attack together with a loss expansive form of oxidation products from the corrosion reactions means that substantial section loss may occur prior to warning signs of longitudinal cracking becoming visible on the surface of the member. This project reports a study into the effects of epoxy coating and Cement Slurry coating on the resistance to corrosion on residual mechanical properties of steel reinforcement conducted through experiment.

1.2 Needs for the Study

Concrete structures in aggressive environment [Marine/Industrial area] are subjected to chloride attack. In order to protect concrete structures from chloride attack in aggressive environment, it is necessary that protective coatings are applied to concrete and steel both to prevent ingress of chlorides.

The metallurgists and electrochemical engineers have developed several methods of protection of steel from corrosion in concrete. According to the booklet prepared by CAMTECH [2014] the most commonly known system in protection of steel from corrosion is,

a. Use of Corrosion Resistance Steel Reinforcement Bars
b. Methods developed by Central Electro – Chemical Research Institute [CECRI], Karaikudi – Tamilnadu
c. Inhibited Cement Slurry Coatings System [Old Method]
d. Cement – Polymer – Composite Coating System [New Method]
e. Hot clip – Galvanizing
f. Fusion Bonded Epoxy Coated Rebars [FBECR]
g. Epoxy – Phenolic Interpenetrating Polymer Network [IPN] Coating for reinforcing steel developed by CBRI, Roorkee
h. Truncated inhabited Slurry Cement base Coating – as used Kankan Railway

Epoxy Phenolic – IPN coated reinforcing bars have emerged as available and cost effective corrosion – system for reinforced concrete structures. According to the original research, the Epoxy Phenolic – IPN system was developed for protection of structural steel sand now extended to rebars. This type of coating is a physical barriers system that prevents moisture and chlorides from coming in contact with the bars. Epoxy Coating is also being regarded now as an electro chemical corrosion barrier which electrically isolated the bars by reducing the flow of corrosion current.

Extensive research has been done and many protective coatings systems have been developed and tried so far all over the world. It has been pointed out by K.Saravanan et al [2007] that most of the Organic and Inorganic Coatings have pinholes and accelerated corrosion of steel takes places through pinholes. In order to prevent the corrosion of steel in pinholes, coatings system containing conducting polymer is highly useful. Conducting polymers has been the topic of the large number of Investigators during last decades.

1.3 Objectives of the Study

The main objectives of this project work are as follows:

To develop a coating system that can be performed quickly and economically.

To develop a reliable adhesion test can be performed respectively at the coating plant and form which test result can be objectively interpreted for quality control.

To determine the effectiveness of organic coatings rebars in corrosion resistance by various electro – chemical studies and microscopic analysis in which the following strategies are studies:

a. The Current flow
b. Potential time behavior
c. Delamination of coating
d. Weight loss
e. Corroded Concrete Morphology

To understand the relationship between Coating adhesion and corrosion protection mechanical split tensile test, pull out test, cathodicdisbondment test are studies as a means of quality control for Epoxy phenolic – IPN and Inhibited Cement Slurry. The main scope is to produce a test that could be easily and practically implemented without special or sophisticated equipment.

In future the effectiveness of coating can be studies in acidic, sulphates, concrete and normal environments. The performance of coating to concrete can be studies instead of rebars. New testing techniques can be adopted with further reinforcement and accuracy.

2. MATERIALS USED

2.1 Cement

Ordinary Portland Cement (OPC) is the most common cement used in the world because of the abundance and low cost to produce it. ... Portland Pozzolana Cement (PPC) is a variation of OPC which includes a mixture of a pozzuolanic material which can increase the strength of the concrete and reduce the amount of OPC used.

2.2 M Sand

Manufactured sand is a substitute of river for construction purposes sand produced from hard granite stone by crushing. The crushed sand is of cubical shape with grounded edges, washed and graded to as a construction material. The size of manufactured sand (M-Sand) is less than 4.75mm.

2.3 EPIDEC EPOXY

Epidec Epoxy is an anti-corrosive coating for varied industrial application. It is a versatile air drying two packs epoxy system that ensures great finish and lasting protection to your industrial structures and components as shown in fig.1

Fig.1 Edipic Epoxy

2.4 TMT BARS

TMT stands for Thermo Mechanically Treated. The TMT bars have a hard outer surface and a softer core. The manufacturing process includes hot rolled steel wires passed through water. This makes the surface hard and keeps the core warmer and softer.

On the other hand HYSD is manufactured by a process of twisting the rod after casting. This by nature creates surface flaws and the yield strength of the rod might get affected.

2.5 CALCIUM NITRITE

Calcium nitrite is an inorganic compound with chemical formula Ca $(NO_2)_2$. In this compound, as in all nitrites, nitrogen is in a +3 oxidation state. It has many applications such as antifreeze, rust inhibitor of steel and washes heavy oil.

3. TESTING OF MATERIALS

3.1 Tests on coarse Aggregate

The coarse aggregate of 12mm size has been used and the properties are given in table 1 below

Table 1 Properties of Coarse aggregate

S.NO	Property	Value
1	Specific gravity	2.82
2	Impact value	2.7%
3	Crushing value	14.36%
4	Water absorption	0.5%

3.2 Tests on PPC Cement

The test on PPC Cement properties is shown in table 2 below

Table 2 Properties of PPC Cement

S.NO	Property	Value
1	Specific gravity	3.02
2	Initial setting time	120min
3	Final setting time	166min

3.3.Tests on M sand

S.NO	Property	Value
1	Specific gravity	2.62
2	Bulk Density	1.57kg/m^3
3	Fineness modulus	2.9

4. EXPERIMENTAL PROCEDURE

4.1 Tensile Strength Test

Tensile strength is a measurement of the force required to pull something such as rope, wire, or a structural beam to the point where it breaks. The tensile strength of a material is the maximum amount of tensile stress that it can take before failure, for example breaking.

There are three typical definitions of tensile strength:

Yield strength - The stress a material can withstand without permanent deformation. This is not a sharply defined point. Yield strength is the stress which will cause a permanent deformation of 0.2% of the original dimension.

Ultimate strength - The maximum stress a material can withstand.

Breaking strength - The stress coordinate on the stress-strain curve at the point of rupture.

4.1.1 Test Method

The tensile strength test is carried out in a Universal Testing Machine (UTM) of 100 ton capacity. The test is carried out with reference to IS 1786: 2008 standard in Thermo Mechanically Treated (TMT) bars of grade Fe 500D. TMT bars of 3 numbers in 12 mm diameter respective for a length of 60 cm is used in this test. The test is carried out both uncoated and coated rebars and the result is arrived.

4.*2* Test Procedure for Tensile Strength Test

A. The diameter of the given rod is measured using vernier caliper.
B. The gauge length s marked on the rod using dot punch.
C. Suitable load range is selected in U.T.M and dial pointer adjusted to zero.
D. The rod fixed with Extensometer s fixed between the tension grips and extensometer dial is adjusted to zero.
E. The specimen is loaded and extensometer readings are noted at regular interval.
F. The extensometer is removed and the specimen is loaded further and the load at yield point, ultimate load and breaking load are noted.
G. After the breaking load the specimen is removed from the grips and final length and diameter of the rod at the breaking point are measured.
H. A graph is drawn by taking load along Y-axis and elongation along X-axis.
I. Also a graph is drawn by taking stress along Y-axis and strain X-axis.

4.3 Torsion Test

Torsion tests can be performed by applying only a rotational motion or by applying both axial (tension or compression) and torsional forces. Types of torsion testing vary from product to product but can usually be classified as failure, proof, or product operation testing.

4.3.1 Test Procedure for Torsion Test

A. Fix the given prepared specimen in the chucks.
B. Ensure that there is no initial twist in the specimen.
C. Reset the angle of rotation and torque values.
D. Rotate the spindle slowly in clock wise direction till angle of rotation comes to 1° and note down the corresponding torque.
E. Similarly rotate the spindle slowly for another 4 reading in the steps 1° rotational angle of the work piece and note down the corresponding torque values.
F. Calculate the modulus of rigidity.

4.3.2. Pull out Test

This test method covers determination of the pull out strength of hardened concrete by measuring the force required to pull an embedded metal insert and the attached concrete fragment from a concrete test specimen or structure. The insert is either cast into fresh concrete or installed in hardened concrete.

4.3.3 Test Specimen For Pull Out Test

Size or the test Specimen **-** The test specimens shall consist of concrete cubes of size given below, with a single reinforcing bar embedded vertically along a central axis in each specimen. The bar shall project down for a distance of about 10 rom from the bottom face of the cube as cast, and shall project upward from the top face whatever distance is necessary to provide sufficient length of bar to extend through the bearing blocks and the support of the testing machine and to provide an adequate length to be gripped for application of load. The cube shall be reinforced with a helix of 6 mm diameter plain mild steel reinforcing bar conforming to Grade I of IS: 432 (Part 1)1966 The average compressive strength of three cubes representing the concrete used for test specimen in 3.t, made and tested in accordance with relevant requirements of IS: 516-1959· shall be 200 to 300 kg/cml at the time of making the pull-out tests. If the range of the compression strength of three cubes tested exceeds 50 kg/cm', the test series shall be discarded. All test specimens and the *control* cubes required to establish the strength of concrete shall be cured under similar conditions. For the purpose of comparing bond resistance of deformed bars and plain bars, the concrete used in both tests should be of the same mix, strength, age and curing. The bars to be tested shall also be of same cross-sectional area and have similar surface conditions (seeNote under 5.2.1).

4.3.4 Test Procedure for Pull Out Test

The pull out test is carried out in a UTM of 100 ton capacity with reference to IS 2770(part 1):1967. This method of test is intended to provide a standardized procedure for comparison of bond characteristics between concrete and different type of reinforcing bars. The test is carried out both uncoated and coated rebar's and the result is arrived.

The test specimen shall be mounted in a universal testing machine in such a manner as shown in fig. that the bar is pulled axially from the cube. The end of the bar at which the pull is applied that which projects from the top of the cube as cast.

4.4 Cathodic Disbondment Test

Cathodic disbondment is the loss of adhesion between a cathodic coating and its metal substrate due to the products of cathodic reduction reaction (corrosion reaction) that take place in the interface of coatings.

Cathodic protection (CP) systems are installed to prevent corrosion of metal. Disbondment of coating occurs when coatings in a cathodic protection system interact either chemically or physically, ultimately causing corrosion beneath the coat.

4.4.1 Cathodic Disbondment

The anodic reaction that occurs at a coating defect is usually coupled to a nearby cathodic reaction beneath the coating.

- Oxygen and water migrate through the coating and support the cathodic reaction. This is possible because of coating permeability.
- Cathodically generated alkalinity can react with the organic polymer to disbond the coating at the interface between coating and metal termed as saponification.
- It has also been theorized that cathodic disbondment may proceed by dissolution of the oxide film by hydroxides rather than by alkaline degradation of the coating itself.
- At cathode hydroxide and at the anode chlorine ions are formed
  Cathode:
  $$2H_2O + 2e^- \longrightarrow H_2 + 2OH^-$$
  Anode:
  $$2Cl^- \longrightarrow Cl_2 + 2e^-$$

On the cathode hydroxide ions can also be formed by reduction of oxygen (O_2) which is generally dissolved in electrolyte cathode.

4.4.2Test Procedure For Cathodic Disbondment Test

A. Cathodic disbondment test is carried out with reference to Ministry of Transportation, Ontario Laboratory Testing Manual the test procedure is follow as,
B. Perform the cathodic disbondment test using the testing equipment as shown in fig.
C. Add approximately 500 ml electrolyte to the beaker.
D. Insert the bar into a beaker, with the sealed end of the bar resting on the bottom end of the beaker. Add the electrolyte until the 100 mm of the bar length is submerged. Connect the negative lead from the D.C. power supply to the grounding screw of the bar.
E. Insert 75 mm of the anode in to the electrolyte. Connect the shunt resistor to the anode and the positive lead of the voltmeter to the calomel electrode and the negative lead to the bar.
F. Turn on the power supply adjust to the power supply until the polarized potential of the steel is stabilized at 1500 ± 20mV with respect to the calomel electrode measure the voltage drop across the shunt resistor using the voltmeter and calculate the current flow. Record the time as the start time.
G. The bars shall remain in the electrolyte, which shall be maintained at a temperature of 23± 2ºC, For a period of 168 ± 2hours. Calculate the current flow.
H. The calomel electrode shall be removed after each potential measurement to avoid the contamination of the electrode.
I. Remove the bar from the beaker.

5. TESTING OF SPECIMENS

5.1 Tensile Strength on Steel

- Gauge length of the rod (L_1) = 60mm
- Diameter of the rod = 12mm
- C.S of the rod(A_1) = 113.09mm^2
- Load at yield point = 58000 N
- Ultimate load = 75000 N
- Breaking load = 68500 N
- Diameter of the rod in mm at the neck
- (after breaking) = 9.5mm

5.1.1 Calculation

1. Stress at Yield Point = 512.86N/mm^2
2. Ultimate Stress = 663.2 N/mm^2
3. Normal Breaking Load = 605.7 N/mm^2
4. Percentage Elongation = 11.6%
5. Percentage reduction in c/s area = 36%
6. Strain = 1.11
7. Actual breaking stress = 948.75 N/mm^2

5.2Torsion Test on Steel

Length of the specimen = 180mm

Diameter of the specimen = 12mm

5.2.1 Modulus of rigidity

G = (T/G)/(Θ/L)

T- Torsion

J – Polar moment of Inertia

G = 4332.27 N/mm^2

5.2.2 Stiffness of the spring = T/(Θ/L)

= $8.82x10^6$ N-mm

5.3 Cathodic Disbondement Test

S. NO	Evaluation Technique	Environment Study	Time Period	Observation	
				Coated	Uncoated
1	CD Test	7%Nacl	60min	No rust formatting on anode rebar	Severe rusting was observed on anode rebar
				No hydrogen evolutions on cathode rebar	Hydrogen evolution occurred on cathode rebar
				Current is 0.00A throughout test period	Increase in current throughout test period

5.4 Pull out Test

S.NO	Specimen	Applied load(kN)	Surface Area(mm^2)	Bond Strength
1	Coating A	66	4900	13.5
2	Coating B	61	4900	12.45
3	Uncoated	52	4900	10.61

3. CONCLUSIONS

The bent –up bar normally use in construction field. But in bent-up bar as a hook type mechanism , that hook fix in the concrete block and pull the bar but in pull out test that bent – up bar is open and so reduce the pull strength. In this experiment the only change the bar size and only same the grade of concrete. 12mm bar size bond strength for specimen A is 13.5N/mm^2, 12mm bar size bond strength for specimen B is 12.45 N/mm^2 and 12mm bar size bond strength for uncoated specimen is 10.61N/mm^2.

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