Improving Corrosion Resistance & Bond Strength of Rebars in Concrete with Sea Water

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ABSTRACT

This experimental work investigates the effect of improving the corrosion resistance of the rebar in concrete and the bond behavior between concrete and rebar's with normal water & sea water & sea water + corrosion inhibitor. Pull-out test was carried out in 400 KN capacity Universal Testing Machine as per procedure outlined in Indian Standards. The tested rebar includes rusted (uncoated) rebar as available in the site and sodium nitrite, sodium benzoate, zinc phosphate these are the anticorrosive coating of different concentration 20g/100ml, 40g/100ml, 60g/100ml of rebar obtained from a source. Concrete of M30 grade were used and totally 33 specimens were tested. The loads at the loaded end slip of 0.01mm and ultimate pull out load were observed. Finally the bond strength of about 30%&27% has been increased by the use of normal and sea water. Corrosion rate has been reduced in the reinforcement with sodium benzoate coating 40g/100ml at 11.62mm/year compare to both normal water and sea water implemented in the concrete cubes.

Keywords: - Sea Water, Corrosion Inhibitor, Pull Out Test, Slip, Bond Strength, Corrosion Rate

1. INTRODUCTION

The world is around sea water is 75% and land is 25% .In this condition, mostly fresh water is not available for construction purpose. So the alternative of fresh water to using of sea water for construction purposes. Many structures have to be built in corrosion prone environment like marine, coastal and industrial areas. As said earlier, the impact of corrosion on economy, serviceability of structures and their durability is very heavy. Application of protective coatings to reinforcement is one of the most commonly adopted methods to address this problem and is widely adopted in practice. The commonly used Anticorrosive coating system includes Sodium Nitrite Coating, Sodium Benzoate Coating, and Zinc Phosphate coating. The applications of coatings change the nature of concrete – steel bar interface that has a bearing on the bond strength between steel bar and concrete. Hence it becomes necessary and relevant to asses of such coatings on the bond strength development.

2. COATING ON REINFORCEMENT

The object of coating on steel bars is to provide a durable barrier to aggressive materials and environment. It is one of the best methods of protecting reinforcing steel from chloride and carbonation induced corrosion. The coatings should be robust to withstand fabrication of reinforcement, pouring of concrete and compaction by vibrators. The coating include sacrificial, sacrificial cum barrier, passivating, passivating cum barrier type. Some of the commonly used coatings are as follows.

- Sodium Nitrite coating
- Sodium Benzoate coating
- Zinc Phosphate coating

2.1 Coating of Reinforcement

3. EXPERIMENTAL INVESTICATION

3.1 Test Programme

Pullout tests were conducted to assess the bond strength between steel and concrete as per IS 2770 (Part I) – 1967 – Methods of testing bond in reinforced concrete. As per the code of the compressive strength of adopted for pull out test shall not exceed 50N/mm^2. Moreover, the widely adopted concrete grade in the construction sites is M30. Hence a design mix for that grade was done and tests were conducted for compressive strength as per BIS 516 – 1968 using trial Mix. Five cube of size 150mm X 150mm X 150mm were cast and the average compressive strength was found to be 32N/mm^2 which validates the design. Twenty seven control specimens in various dosages with 16mm diameter rebar. Totally thirty three specimens were cast and tested to assess bond strength development.

Fig 3.1 Arrangement Inside The Mould For Bond Strength Test Specimen

3.2 Test Procedure

Concrete cubes of size 150mm were cast with centrally embedded rebar provided up to 20mm from the face of the cube. The rebar extended over the top face of the cube. The rebar extended over the top face for a sufficient length to facilitate gripping of rebar on the machine. Helical reinforcement of 6mm diameter is wound with a pitch of 25mm for a diameter of 130mm and kept inside the mould. The rebar bonded length in concrete is restricted to 5 times of diameter rebar.

Fig 3.2.1. View of Bond strength Test Specimen after cement caping

To avoid bond near loaded end, plastic sleeves were provided in the remaining length. figure 3.1 shows arrangement inside the mould for bond strength test. After the curing period, a neat cement gaping was done on the top face of the specimen to facilitate proper seating of specimen on the testing facility. Figure shows the view bond strength test specimens with cement caping.

3.3 Test Set – Up

The pull out test is carried out using 40T universal testing machine. one dial gauge meter of least count 0.01 mm are attached; one touching the projecting tip of the reinforcement of 10 mm and the other at 250 mm below concrete face on the opposite face. The elongation of the bar is compensated to compute the slip. The difference in readings of the one dial gauge readings is taken as the relative slip of the rebar with the concrete surface. The test set up is shown 3.3.1.

Fig.3.3.1.Arrangement of pullout test in UTM

4. RESULT AND DISCUSSION

4.1 Bond Stress

For each load level, the average bond stress τ is calculated as the average stress between the reinforcing bar and surrounding concrete along the embedded portion of the bar as follows:

$$\tau = \frac{F}{\pi d l}$$

where ,

F - the pullout force of the steel bar

l - embedded bond length

d - diameter of the steel bar.

Table 5.1 presents the steel corrosion η, the average crack width Wave, the ultimate pullout force of the steel bar Fp, the corresponding ultimate bond stress τu, the free end slip Sf and the load end Slip Sl.

4.2 Weight Loss Analysis

Before the samples were cleaned with acetone, the samples were weighed for the original weight (*wo*) by using Sartorius Cole-Polmer analytical balance (readability:0.0001g). Before weighing, the sample was cleaned with distilled wate Corrosion rate is calculated assuming uniform corrosion over the entire surface of the coupons. Corrosion rates, *CR* are calculated from weight loss methods. The formula used to calculate corrosion rate is as in Equation 1 [6]: r and dried. Finally, the sample was washed with distilled water, dried and weighed in order to obtain the mfinal weight (*w1*).

$$CR \text{ (mm /y)} = 87.6 \times (W / DAT)$$

Where:

CR = Corrosion Rate (mm/y)

W = weight loss in milligrams

D = metal density in g /cm^3

A = area of sample in cm^2

T = time of exposure of the metal sample in hours

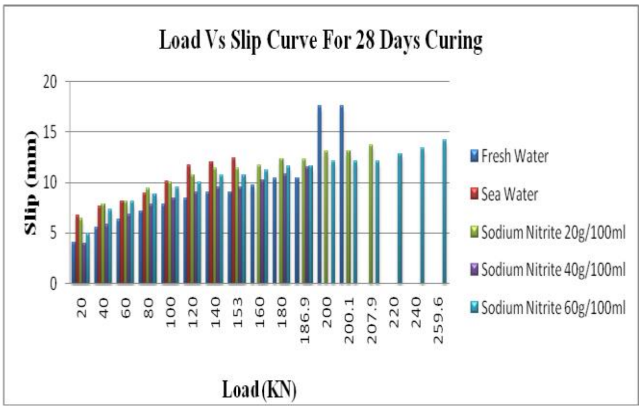


Fig 4.1 Comparison Graph for Load Vs Slip

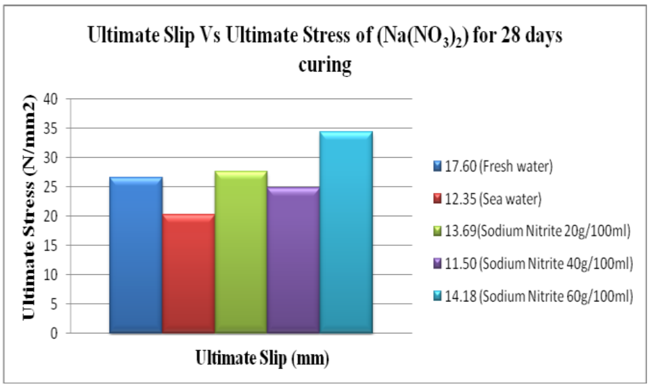


Fig 4.2 Comparison Graph for Slip Vs Stress

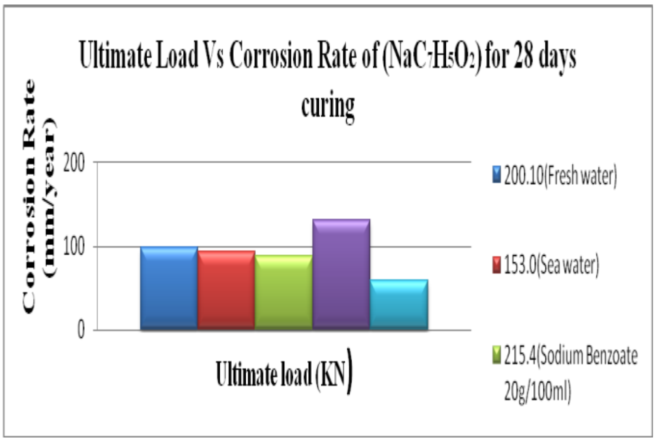
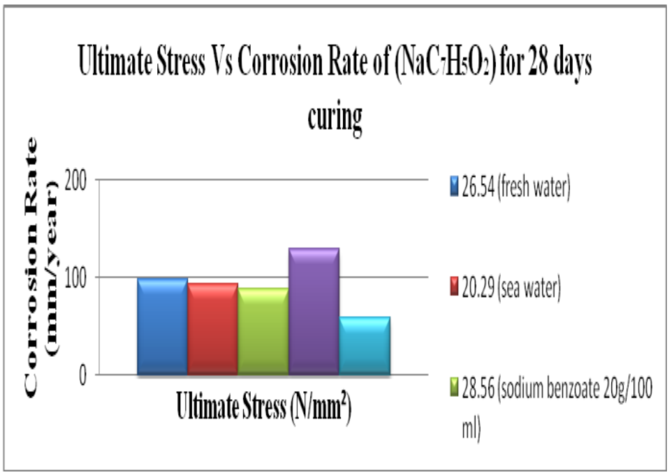


Fig 4.3 Comparison Graph Ultimate Load Vs Corrosion Rate



4.4 Comparison Graph Ultimate Stress Vs Corrosion Rate

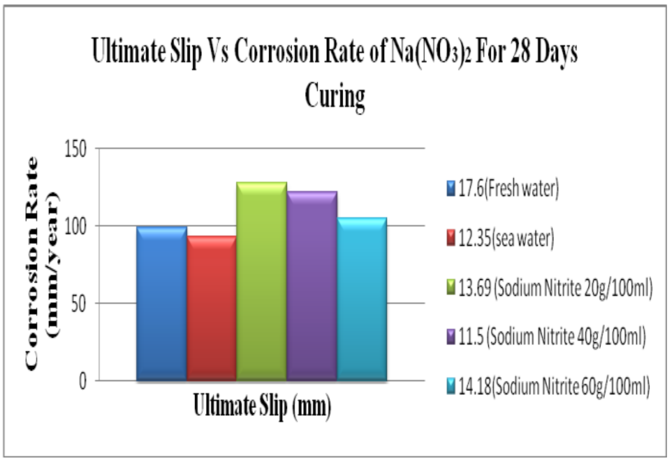


Fig 4.5 Comparison Graph Ultimate Stress Vs Corrosion Rate

5. CONCLUSION

The specimen were casted using sea water and in order to reduce the corrosion rate different kinds of coating were given to the reinforcement bars. The influence of stirrups, concrete type and Steel corrosion on degradation of bond strength was investigated. Zinc Phosphate and Sodium Benzoate coating gives best results when compared with conventional concrete specimens, stirrups can effectively increase the bond rigidity and ultimate bond strength and reduce the difference in bond behavior.

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