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IMPROVING CORROSION RESISTENANCE AND 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 ofthe rebar in concrete and the bond behavior between concrete and rebar's with normal water & sea water & sea water + corrosion inhibitor. 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 casted.

Keywords: Sea Water, Corrosion Inhibitor, Sodium Nitrite, Sodium Benzoate, Zinc Phosphate, Corrosion Rate

I. INTRODUCTION

Concrete is a mixture of cement, fine aggregate , coarse aggregate and water. The chemical reaction between water and cement called hydration makes the mixture hard which is called concrete. Concrete is strong in resisting compressive forces effectively, but is weak in resisting tension. In order to make concrete resist tensile forces steel bars are introduced inside it, such concrete is called reinforced cement concrete or simply RCC. RCC structures became popular in the past few decades and are very much in use even now many RCC building and bridges have been constructed in the past and are still under construction .Though RCC is the most widely adopted method of construction there are some problems that need to be addressed in order that they function successfully for the design period. The most important problem affecting the performance of RCC structures is corrosion of steel rears. Corrosion not only reduces their load carrying capacity. The bond between the bars and the surrounding concrete is a vital requirement for RCC structures. Bond strength is also affected by corrosion of steel bars. The problem of corrosion is more severe in coastal, marine environments. India which has a long coast line is more vulnerable to corrosion. If the sea water is used in making the RCC the steel rods are corroded easily and as a result the structure gets collapsed. The corrosion inhibitors are used to improve corrosion resistance in rebar's. The corrosion inhibitors i.e., chemicals are coated over the steel bars (Here using 16mm diameter bars) in various dosages. The various dosages of chemicals are used to prepare a comparative statement also.

1.1 CORROSION MECHANISM

Steel corrodes it is not a naturally occurring material. Rather, iron ore is smelled and refined to produce steel. The production steps that transform iron ore into steel add energy to the metal. Steel , like most metals except gold and platinum, is thermodynamically unstable under normal atmospheric conditions and will release energy and revert back to its natural state -iron oxide, or rust this process is called corrosion.

For corrosion to occur, these elements must be present:

- There must be at least two metals (or two locations on single metal) at different energy levels
- An electrolyte
- A metallic connection

In reinforced concrete, the rebar may have many separate areas at different energy levels. Concrete acts as the electrolyte, and the metallic connection is provided by wire ties, chair supports, or the rebar itself.

Corrosion is an electrochemical process involving the flow of charges (electrons and ions). Figure 1.1 shows the mechanism of corrosion of steel in concrete. At active site on thbar, called anodes, iron atoms lose electrons and move ninto surrounding concrete as ferrous ions. This process is called a half – cell oxidation reaction , or the anodic reaction ,and is represented as :

$$\mathbf{2Fe \longrightarrow 2Fe^{2+} + 4e^-}$$

The electrons remain in the bar and flow to sites called cathodes , where they combine with water and oxygen in the concrete. The reaction at the cathode is called a reduction reaction. A common reduction reaction is :

$$\mathbf{2H_2O + O2 + 4e^- \longrightarrow 4OH}$$

To maintain electrical neutrality , the ferrous ions migrate through the concrete pore water to these cathodic sites where they combine to form iron to form iron hydroxides, or rust :

$$\mathbf{2Fe^{2+} + 4OH^- \longrightarrow 2Fe(OH)}$$

Oxygen dissolves quite readily in water and because there is usually an excess of it , it reacts with the iron hydroxide.

$$\mathbf{4e(OH)_2 + O_2 \longrightarrow 2H_2O + 2Fe_2O_3.H_2O}$$

Iron hydroxide + oxygen ⟶ water + Hydrated iron oxide (rust)

This initial precipitated hydroxide tends to react further with oxygen to form higher oxides. The increases in volume as the reaction products react further with dissolved oxygen leads to internal stress within the concrete that may be sufficient to cause cracking and spalling of the concrete cover. Low – permeability concrte can be attained by decreasing the water to cementations materials ratio of the concrete and the use of pozzolans and slag . pozzolans and slag also increase the concrete resistivity thus reducing the corrosion rate even after it initates. ACI 318 , Building Code Requirements for Structural concrete provides minimum concrete cover requirements that will help protect the embedded metals from corrosive materials.

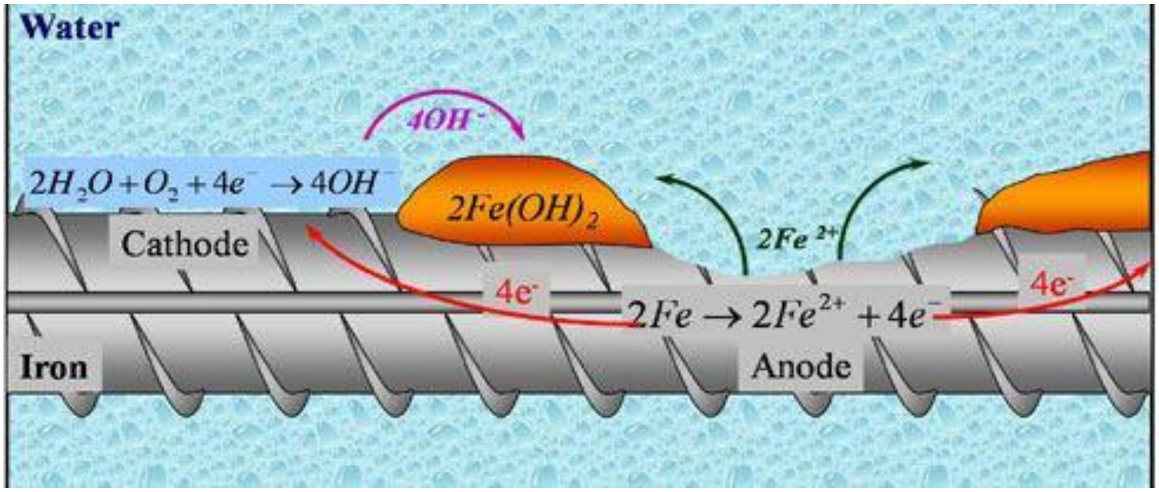

Figure 1.0 Corrosion mechanism

II. EXPERIMENTAL INVESTIGATION

A. Cement

Cement used for the specimen was ordinary Portland cement. The cement used was in standard gunny bags and transferred to latter to air tight steel drums to avoid deterioration of the quality confirming IS 8112:1989

B. Water:

(i) Normal Water (Portable Water):

Water is an important ingredient of concrete. As a general guidance, if the water is fit for drinking it is fit for making concrete. However, some water containing a small sum of salt is not suitable for concrete. Other yard-stick adopted is if the PH is between 6 to 8 the water is accepted to be suitable.

C.SEA WATER:

Some waters are not fit for drinking may be suitable for concrete making provided that they acceptance criteria. Excessive impurities in mixing water affect setting time and concrete strength and also efflorescence (deposits of white salts on the surface of concrete), staining, corrosion of reinforecement, volume changes, and reduced durability.

Although the vast majority of seawater has a salinity of between 3.1% and 3.8%, seawater is not uniformly saline throughout the world. Where mixing occurs with fresh water runoff from river mouths or near melting glaciers, seawater can be substantially less saline. The most saline open sea is the Red Sea, where high rates of evaporation, low precipitation and river inflow, and confined circulation result in unusually salty water. The salinity in isolated bodies of water (for example, the Dead Sea) can be considerably greater still.

D.SODIUM NITRITE COATING

Sodium nitrite is the inorganic compound with the chemical formula NaNO2. It is a white to slightly yellowish crystalline powder that is very soluble in water and is hygroscopic. It is a useful precursor to a variety of organic compounds, such as pharmaceuticals, dyes, and pesticides, but it is probably best known as a food additive to prevent botulism.

E.SODIUM BENZOATE COATING

Sodium benzoate

Sodium benzoate has the chemical formula $NaC_7H_5O_2$;it is a widely used food preservative, with E numberE211. It is the sodium salt of benzoic acid and exists in this form when dissolved in water. It can be produced by reacting sodium hydroxide with benzoic acid. Benzoic acid occurs naturally at low levels in cranberries, prunes, greengage plums, cinnamon, ripe cloves, and apples.

F.ZINC PHOSPHATE COATING

Zinc phosphate

Zinc phosphate (Zn3(PO4)2) is an inorganic chemical compound used as a corrosion resistant coating on metal surfaces either as part of an electroplating process or ap-plied as a primer pigment (see also red lead). Zinc phos-phate coats better on a crystalline structure than bare metal, so a seeding agent is often used as a pre-treatment. One common agent is sodium pyrophosphate.

III .EXPERIMENTAL INVESTIGATION

Cement mortar / concrete is a combination of cement, aggregate and water with or without some chemical or mineral admixtures such as jellinium , plasticizers and fillers etc. the incorporation of admixtures leads to a matrix with a sufficient consistency in the fresh state than in a conventional mortar/ concrete. The rheological properties of the concrete are there by appreciably modified.

In the recent times, jellinium are effectively employed to protect the concrete against repair from corrosion effects. The incorporation of jellinium will definitely have an influence on the rheological properties of the concrete. There is a possibility for change in strength properties such as compressive strength, flexural and tensile strength , bond strength with steel etc. and durability properties such as water absorption, chloride penetration, resistance to freeze and thaw, chemical attack etc.

Moreover concrete structures exposed to aggressive environments are faced with the problem of cracking and chemical penetration inside the concrete. The development of crack at the interface reduces the bond strength between old and new concrete and also has an influence on other durability related parameters. This chapter details the materials and mix proportion for M30 concrete which is used as a control concrete for all the coated rebars during specimen preparation.

A.SLUMP CONE TEST

The slump is taken for each mixing of concrete with 7.5% replacement of silica fume for cement in high performance of concrete and polypropylene and polyester added with some percentage of fibers and also 40 % replacement of copper slag from river Sand in high performance of concrete and polypropylene and polyester added with some percentage of fibers. The results show that slump of concrete made with high performance concrete with added polypropylene and polyester and some of fibers

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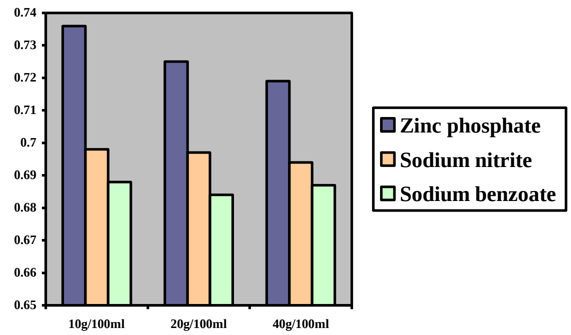
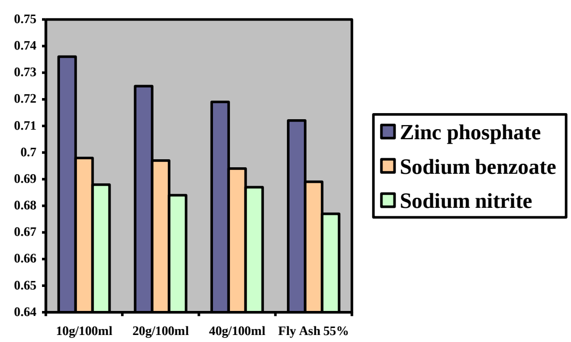


B.COMPACTION FACTOR TEST

Compacting factor test also used to determine the workability of fresh concrete. It is not used on site testing because the apparatus is very heavy. According to Street works the compacting factor test gives a more accurate workability of fresh concrete than slump test. It mentioned that the compacting factor test also known as the "drop test", which measures the weight of fully compacted concrete and compare it with the weight of partially compacted concrete



Corrosive Coating Of Reinforcement

The introduction of coating at the steel concrete interface will definitely modify the bond behaviour of steel with concrete.

The application of protective coating to rebar becomes an efficient and popular method of protecting steel rebar from corrosion inside the concrete.

The most widely used commercial coating methods are Sodium nitrite, Sodium benzoate, zinc sulphate and also act as a inhabitater .

Now a days a simple, Cement Polymer Anticorrosive Coating was developed and used in various parts of South India.

It has been reported that epoxy coated bars offers less slip resistance and bond strength as compared to uncoated bars.

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Coated Rebar's And Spring Arrangements

CUBE CASTING

The mix design for M30 concrete was carried out as per Indian standard (IS) method. The concrete material comprises of 20 mm downgraded jelly, natural sand available from local source, 43 grades Portland Pozzolona Cement (PPC) obtained from single source and potable water. The Mix ratio obtained is 1 : 1.37 : 3.23, w/c ratio 0.5. The steel rebar comprises of heavily rusted 16 mm TMT rebar obtained from a single length. The coating material is a commercially available corrosion inhabitater.The type of rebar used in the study includes rusted rebar (uncoated bar) as available in the site, and the rebar coated with anticorrosive coating.

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CONCRETE CUBES IN CURING TANK

RESULTS AND DISCUSSION

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.

(i) Bond Stress

Arrangement of pullout test in UTM machine

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:

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

where ,

F - the pullout force of the steel bar
l - embedded bond length
d - diameter of the steel bar.

ii) Weight loss analysis

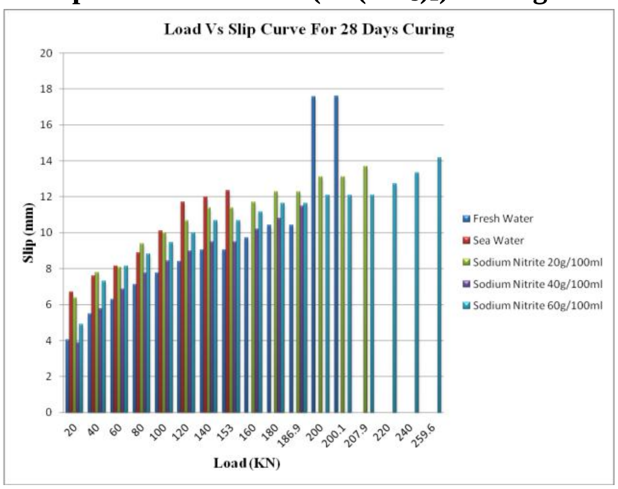
$$CR\ (\text{mm/y}) = 87.6 \times (W / DAT)$$

Where:

W = weight loss in milligrams
D = metal density in g /cm3
A = area of sample in cm2
T = time of exposure of the metal sample in hours

I.LOAD VERSUS SLIP RELATIONSHIP

Fig.5.3.1.load vs slip of sodium nitrite ($Na(NO_3)_2$) coating for 28 days curing



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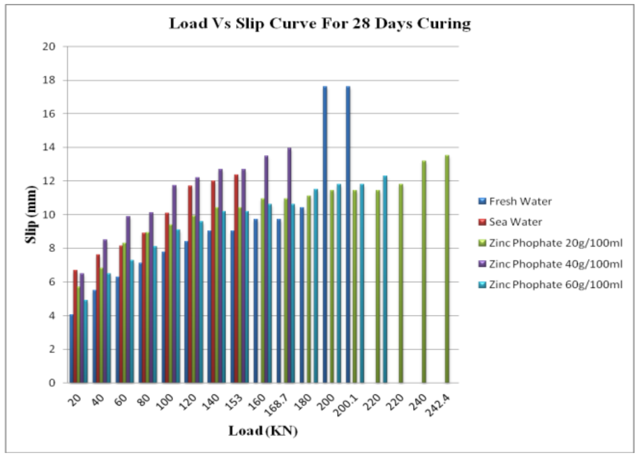

Fig.5.3.8.load vs slip of zinc phosphate $Zn(PO_4)_2$)coating for 28 days curing

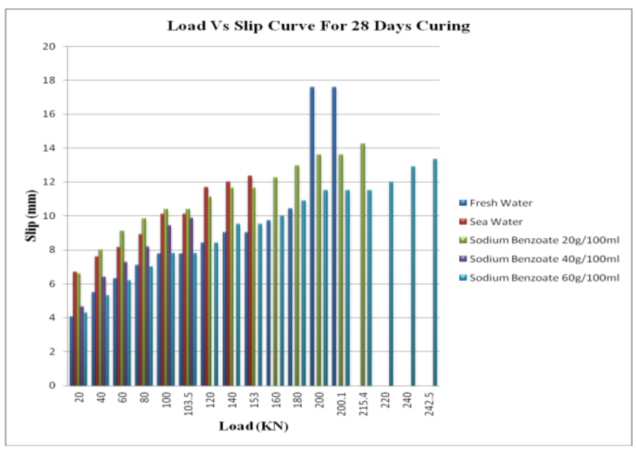

Fig.5.3.9.load vs slip of sodium Benzoate (NaC_7H5O_2) coating for 28 days curing

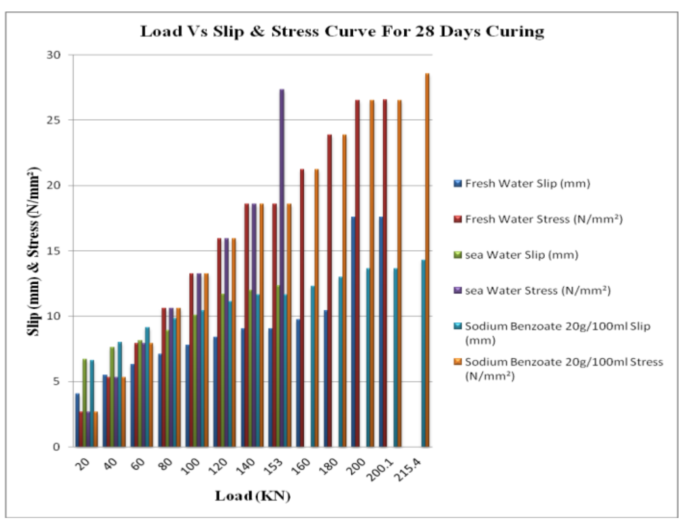

Fig.5.3.34.load vs slip &stress of sodium Benzoate (NaC_7H5O_2) coating for 28 days curing

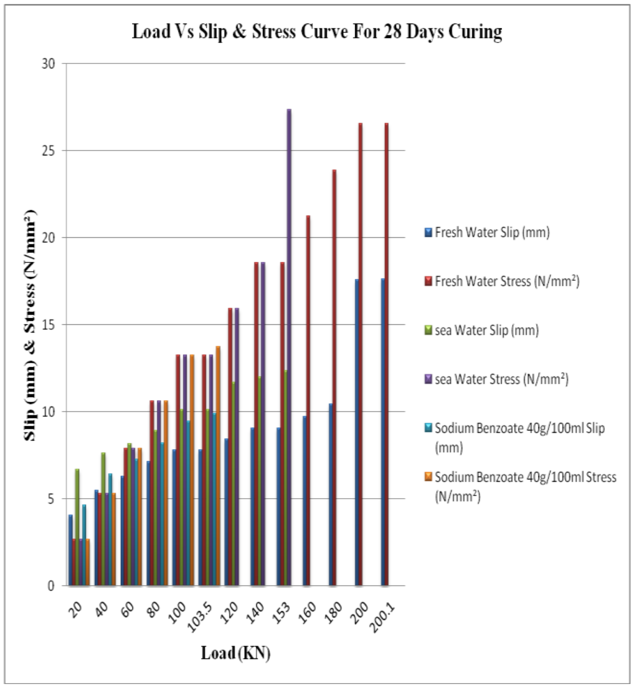

Fig.5.3.35.load vs slip &stress of sodium Benzoate (NaC_7H5O_2) coating for 28 days curing

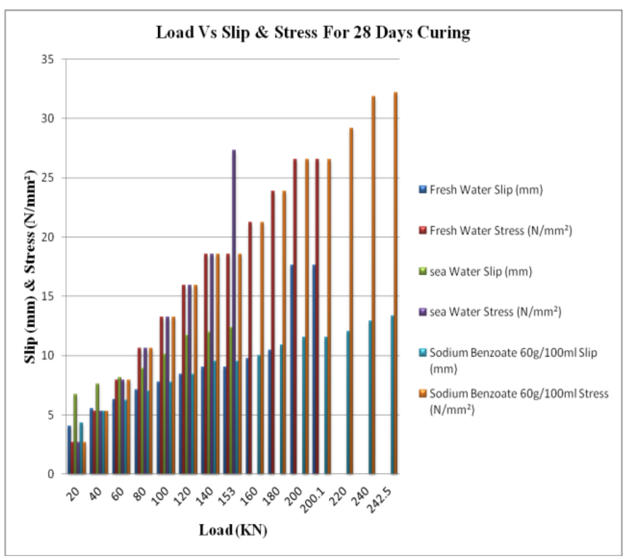

Fig.5.3.36.load vs slip &stress of sodium Benzoate (NaC_7H5O_2) coating for 28 days curing

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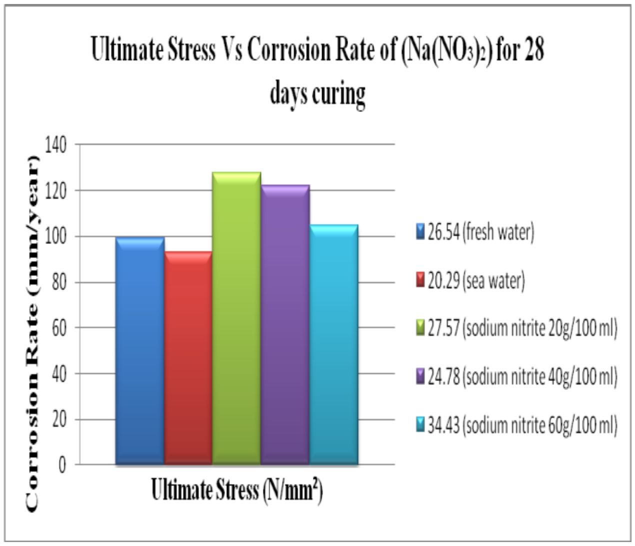

Fig.5.3.48.Ultimate Stress vs Corrosion Rate of sodium Nitrite ($Na(NO_3)_2$) coating for 28 days curing

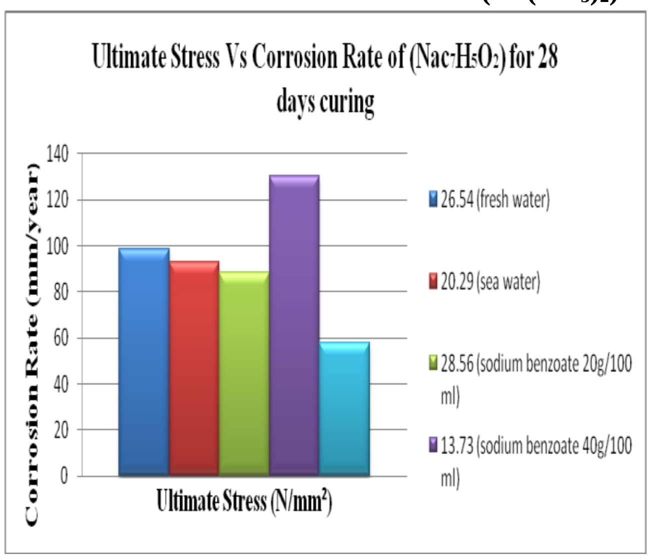

Fig.5.3.54.Ultimate Stress vs Corrosion Rate of sodium Benzoate ($NaC_7H_5O_2$) coating for 28 days curing

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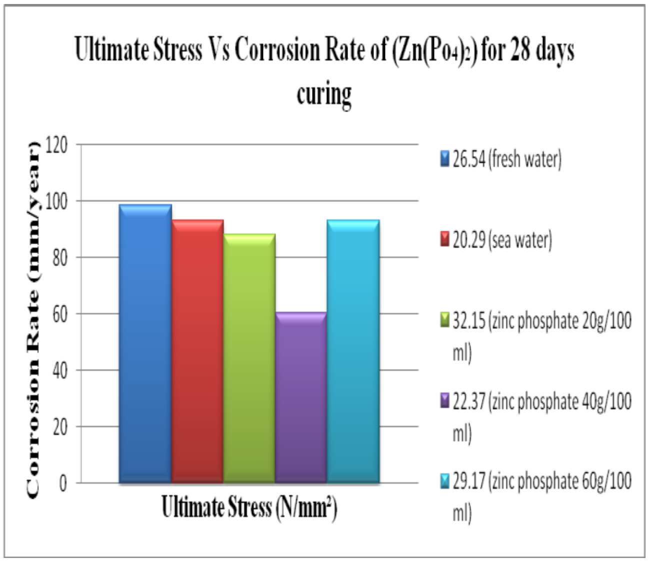

Fig.5.3.51.Ultimate Stress vs Corrosion Rate of Zinc phosphate ($Zn(PO_4)_2$) coating for 28 days curing

CONCLUSION

The experimental results show that the compressive strength of concrete is the optimal mix proportion is 20g/100ml of sodium nitrite. Hence sodium nitrite can be used in concrete

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INFLUENCE OF PROTECTIVE COATING ON BOND STRENGTH DEVELOPMENT OF STEEL WITH CONCRETE

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CORROSION PROTECTION OF REBARS IN CONCRETES

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Bond of High Strength Concrete with High Strength Reinforcing Steel Muhammad N.S. Hadi Faculty of Engineering, University of Wollongong, Wollongong 2522, Australia

BOND STRENGTH OF CONCRETE WITH THE REINFORCEMENT BARS POLLUTED WITH OIL
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