

PERFORMANCE OF BLENDED CORROSION INHIBITORS FOR REINFORCED CONCRETE

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Abstract

Use of chemical corrosion inhibitors has been recognized as one of the effective way of controlling rebar corrosion in reinforced cement concrete (RCC). Corrosion inhibiting admixtures fall into the specialty admixture category and are used to slow down corrosion of reinforcing steel in concrete. The addition of corrosion inhibitors to the mix, offers a viable corrosion protection measure. There are generally three groups of inhibitors: anodic, cathodic and mixed inhibitors. The effect of these chemicals on various physical properties of cement such as setting time, pH, and compressive strength needs to be explored before use. In the present investigation an attempt has been made to mix two commercially available corrosion inhibitors and evaluate its effect on setting time, pH and compressive strength. In the next part of the study electrochemical test involving the blended chemical corrosion inhibitor were also conducted on RCC slab specimen. Corrosion kinematic parameters have been estimated using potentiodynamic polarization tests. It has been observed that the corrosion inhibitor does not have any adverse effect on physical properties of cement and cement concrete. The low corrosion current density exhibited by the inhibitor proves their potential in controlling corrosion initiation and propagation.

Keywords - Corrosion inhibitors, setting time, compressive strength, corrosion kinematic parameters

1. INTRODUCTION

Reinforced concrete is a very versatile construction material. Properly designed concrete structures are both strong and durable. However, concrete structures are vulnerable to a number of factors that can cause deterioration. Deterioration can result in loss of strength and unsafe conditions. Therefore it is important to have an understanding of the vulnerabilities of concrete structures in order to help minimize long-term repair and maintenance costs.

Concrete deterioration typically occurs when the material is exposed to weather, water or chemicals over an extended period of time. When protected from these elements, as in the case of internal members of enclosed commercial and institutional buildings, reinforced concrete can be expected to perform for decades with very little maintenance. However, in many cases, concrete can be exposed to environments that promote deterioration. Examples of these types of environments include parking garages, exterior balcony slabs, and industrial structures where the concrete is exposed to process chemicals. Long-term deterioration can occur at the embedded reinforcing steel as well as at the exposed concrete surface.

The deterioration of reinforced cement concrete is due to the corrosion of the reinforcing steel has become a major problem. It has received worldwide attention and code of practices of different countries has suggested measures to control the steel corrosion but evidence of corrosion of steel in concrete continues to be reported in field situations. The corrosion of steel reinforcement in concrete structures leads to concrete fracture, loss of bond between steel and matrix and reduction in strength and ductility. As a result, safety,

serviceability and durability of concrete structures are reduced.

During the last few decades the corrosion problem in reinforced concrete has been extensively investigated by many researchers. Corrosion inhibitors are one of the most cost-effective solutions to rebar corrosion problem in concrete. Corrosion inhibiting admixtures fall into the specialty admixture category and are used to slow down corrosion of reinforcing steel in concrete. In order to protect metallic materials against corrosion, certain inorganic and organic products, called corrosion inhibitors, are added in small concentration to the aggressive medium [1]. The addition of corrosion inhibitors to the mix, offers a viable corrosion protection measure. There are generally three groups of inhibitors: anodic, cathodic and mixed inhibitors. Anodic inhibitors reduce the corrosion rate by reacting with the corrosion products and form a protective film. Cathodic inhibitors reduce the corrosion rate by reacting with the cathode sites (as an oxygen-barrier) on the steel. Passivating inhibitors like nitrites represent special types of anodic inhibitors and they are generally very effective if present in sufficient concentrations. Mixed inhibitors both influence the anodic and cathodic reaction sites, by forming an adsorption film on the metal surface. These adsorption type inhibitors are typically organic compounds [2-3].

In recent years, results of many investigations and review articles have been published on organic migrating corrosion inhibitor (MCI), which is mainly composed of an amino carboxylate or amino alcohol. The inhibitors are either admixed or directly applied to the concrete surface and they act under bipolar mechanism and penetrate even dense concrete by virtue of their vapour pressure and affinity for

the embedded steel in concrete. Water based mixtures of amines and esters were supposed to form a protective organic layer on the steel bars through a chelation process. The addition of corrosion inhibitors to the mix, offers a viable corrosion protection measure [4-5].

Rosenberg and Gaidis [6] have investigated the inhibition performance of calcium nitrite in simulated concrete pore solution by potentiodynamic polarisation study and found that calcium nitrite increased the breakdown potential for carbon steel in chloride containing saturated $Ca(OH)_2$ solution. Berke [7] also presented similar results. Neagle [8] proved the effectiveness of some organic corrosion inhibitor through electrochemical tests. Dillard [9] found that the sodium tetra borate inhibitor forms a protective layer on metal surface through the reaction of borate and oxygen, but it directly depends on pH of the pore solution. Sagoe-Crentsil, Yilmaz and Glasser [10] have found that the water soluble carboxylic acid is an effective inhibitor in presence of 2.5% chloride contamination. A series of laboratory trials were undertaken to assess the corrosion inhibitor under chloride condition [11]. A study by [12] using the calcium nitrite in cement paste pore solution containing sodium chloride by potentiodynamic polarization method revealed that the passivity break down at a lower potential in the inhibited solution.

In the present study, an attempt has been made to investigate the behaviour of the blend of two corrosion inhibitors viz. Calcium Nitrite and Calcium Hypophosphite added in equal quantity. Physical properties tests of the cement and concrete in the presence of these inhibitors and potentiodynamic polarization tests were conducted.

2. EXPERIMENTAL INVESTIGATIONS

The effect of chosen corrosion inhibitors on setting time, pH and compressive strength has been studied. In the next part of the study electrochemical test involving these chemical corrosion inhibitors were also conducted.

2.1 Setting Time Test

Setting time tests were carried out as per the recommendations of the IS: 4031(Part 5) [13] using 43-Grade Ordinary Portland cement. In Blank (control) specimen, no inhibitor was mixed. 3% dose of the blended inhibitor by weight of the cement was used. The setting time values are given in Table-1.

2.2 Test for pH

pH is another important parameter governing the corrosion and its propagation. Four different mediums were taken for this part of the study. Tests were conducted for both potable and distilled water at a constant temperature of 28 ± 2 °C and the results are tabulated in Table-2.

2.3 Compressive Strength Test

To investigate the effect of corrosion inhibitors on the compressive strength of mortar, the mortar cubes of size

70.6×70.6×70.6 mm were tested after 3, 7, 14 and 28 days of curing as per the recommendations of IS: 4031(Part 6). Effect of corrosion inhibitors on compressive strength of cement concrete (mix ratio 1:2:4) were also determined by testing standard cube of size 150×150×150 mm, Results has been presented in Tables 3-4.

2.4 Electrochemical Test

Electrochemical studies (Tafel extrapolation and AC impedance tests) were also undertaken. Electrochemical System Model "Gill AC" (500 mA/ 100 kHz/ Guard Ring of ACM instruments, U.K.) was used for these experiments. The instrument had inbuilt software support to evaluate corrosion kinetic parameters. The experiments were carried out at a constant temperature of 28 ± 2 °C. The test specimens are shown in Figs.1-2. The test specimens were prepared using river sand (fineness modulus - 2.6) and coarse aggregate (fineness modulus - 4.8). Blended corrosion inhibitor dose of 3% was used. An inhibitor free test specimen was also prepared to serve as control. Both the categories of test specimens were subjected to alternate wetting and drying cycles of one week duration each. Specimens were tested after an exposure of 72 weeks. The result of the electrochemical tests is presented in Figs.3-6.

3. DISCUSSION ON TEST RESULTS

The results of the setting time of the cement after adding 3% dose of the inhibitors are given in Table - 1. It has been observed that the initial and final setting time are reduced to some extent, however the values remains within the permissible limits of the codal provisions.

The effect of addition of inhibitors on pH has been tabulated in Table - 2. 3% concentration of the blended inhibitor increases the pH value marginally. It is interesting to note that when the inhibitor was tested in cement slurry condition the value of pH rose to around 12, which is considered to be fairly alkaline.

The results of mortar and concrete cube compressive strength are given in Tables 3-4. Due to the addition of 3% dose of blended inhibitor the compressive strength has been observed to be more than the control throughout the observation period.

The results of the electrochemical test are presented with the help of Tafel plots, Nyquist, Bode and Theta plots (Figs.3-6). Reasonably low corrosion current density thereby lower corrosion rates as compared to the blank specimen are clear indicator of the effectiveness of both the blended inhibitor.

4. CONCLUSION

Properties investigated viz. Setting time, pH and compressive strength tests clearly indicate that the addition of the blended inhibitors do not have any adverse effect. The low corrosion current density exhibited by the inhibitor proves their potential in controlling corrosion initiation and propagation. Long term studies with varying dose of

corrosion inhibitors are needed for making final recommendations with regard to the dose of these inhibitors for the protection of steel reinforcement in concrete.

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Table – 1: Effect of Corrosion Inhibitor on Setting Time of Cement

System	Initial Setting Time (minutes)	Final Setting Time (minutes)
Blank	103	325
3% dose blended corrosion inhibitor	87	296

Table- 2: Effect of Corrosion Inhibitor on pH

System	pH in Potable water	pH in Distilled water
Blank	7.5	7.3
Cement (Slurry)	12.2	12.2
3% dose blended corrosion inhibitor	7.6	7.5
3% dose blended corrosion inhibitor + Cement (Slurry)	12.2	12.0

Table – 3: Effect of Corrosion Inhibitor on Compressive Strength of Mortar Cube

Specimen Description	Compressive Strength of Mortar Cube in N/mm ²			
	3 days	7 days	14 days	28 days
Blank	20.1	25.5	30.0	43.2.0
3% dose blended corrosion inhibitor	21.4	27.9	35.0.0	48.1

Table – 4: Effect of Corrosion Inhibitor on Compressive Strength of Cement Concrete (Mix 1:2:4)

Specimen Description	Compressive Strength of Concrete Cube in N/mm ²	
	7 days	28 days
Blank	15.5	22.2
3% dose blended corrosion inhibitor	16.4	26.1



Fig. 1: Control specimen



Fig. 2: Inhibited specimen

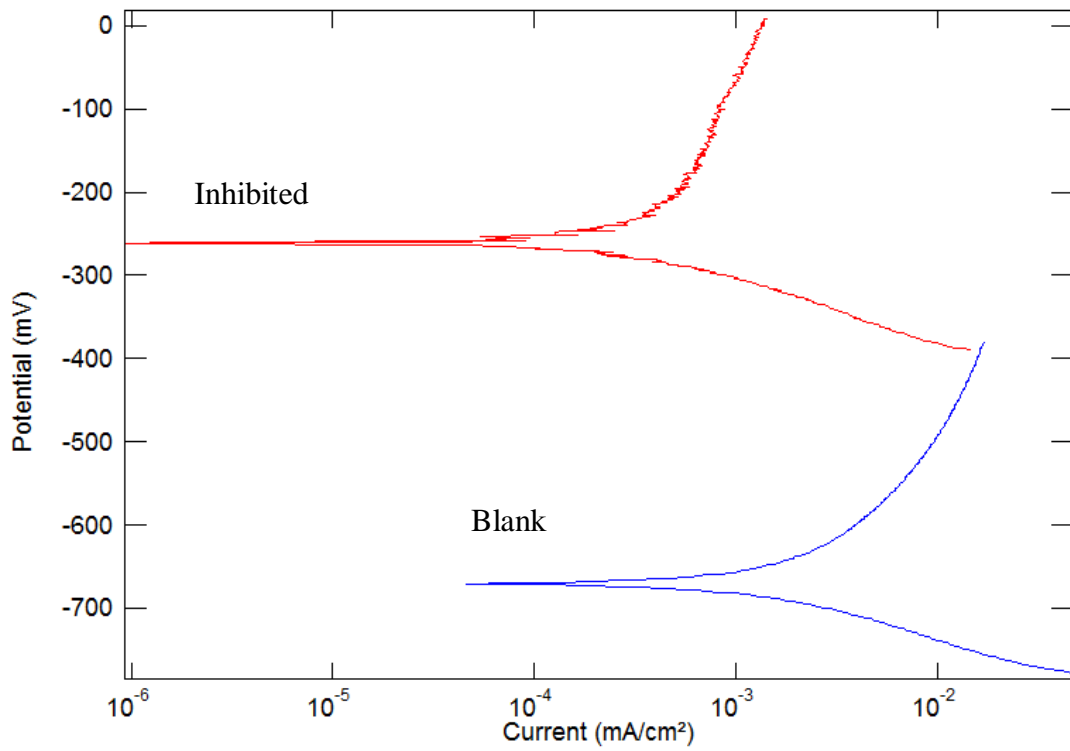


Fig. 3: Tafel Plot for the Control and the inhibited specimen

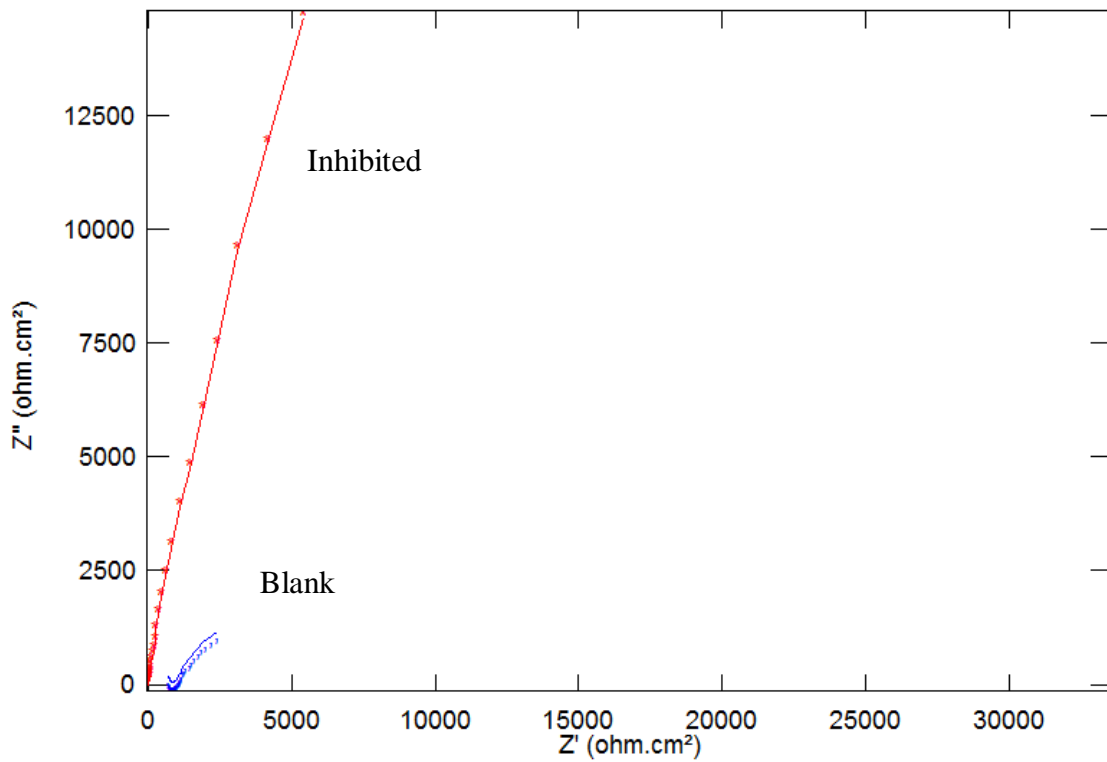


Fig. 4: Nyquist Plot for the Control and the inhibited specimen

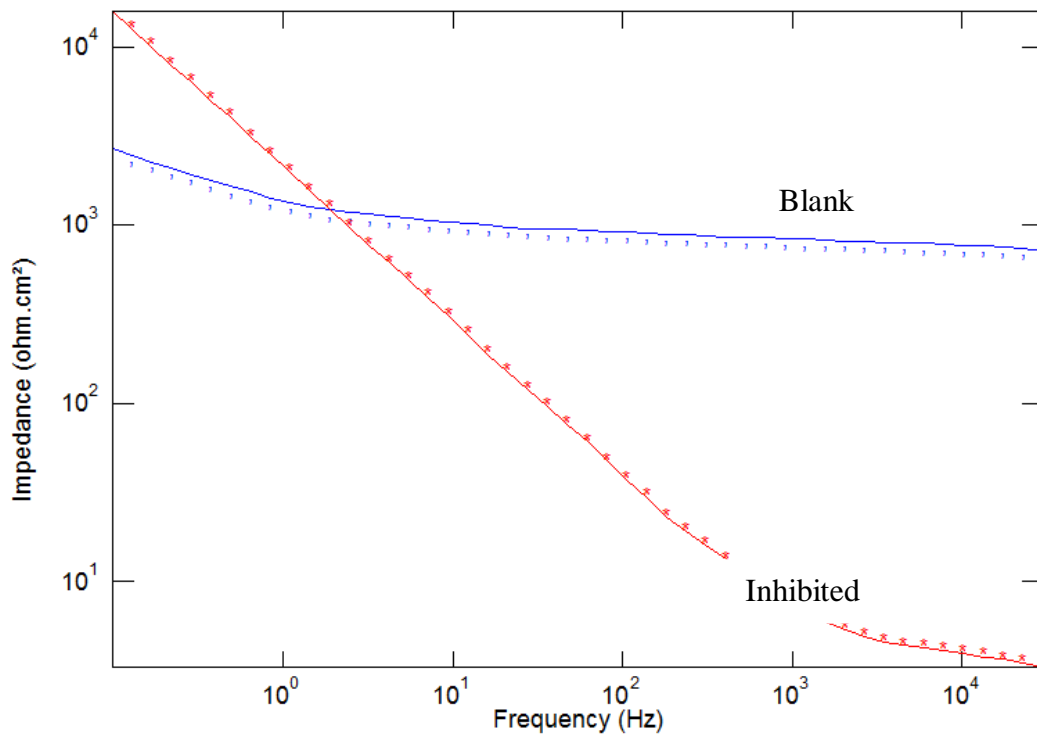


Fig. 5: Bode plot for the Control and the inhibited specimen

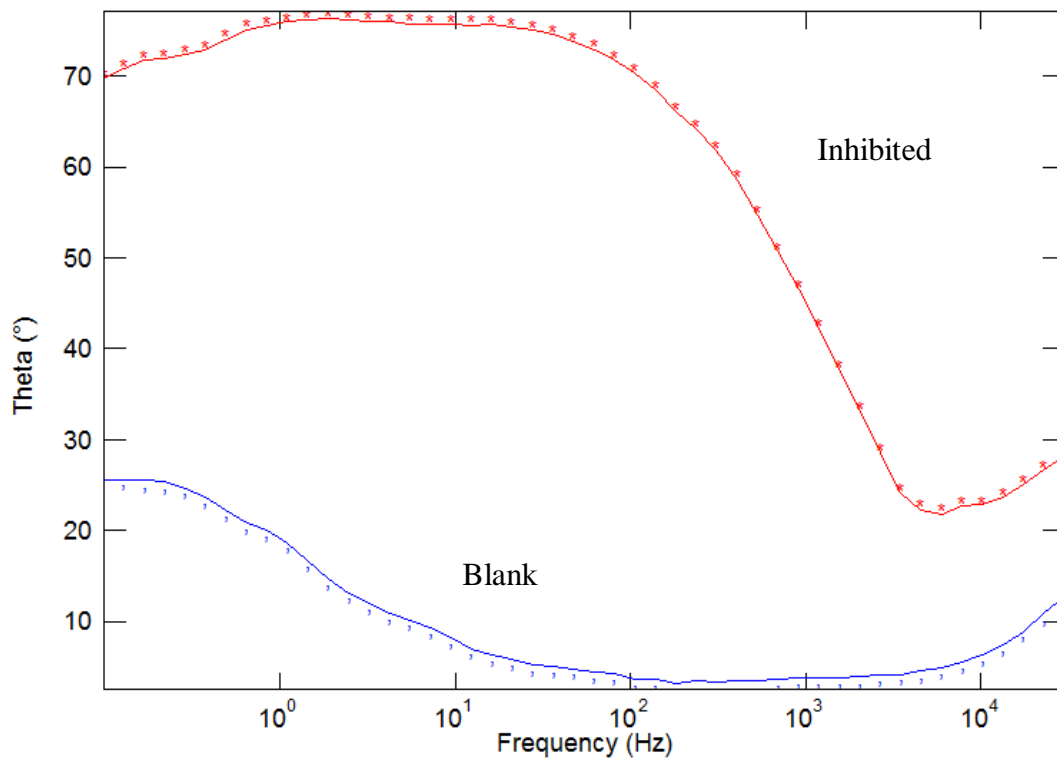


Fig. 6: Theta plot for the Control and the inhibited specimen