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Effect of Corrosion Inhibitor on Cement Mortar Exposed to Corrosion Environment

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ABSTRACT: Corrosion is a phenomena that leads to the growth of rust on steel reinforcement in RCC Concrete structures when exposed to various environmental conditions. The corrosion of steel in reinforced concrete affects its durability and can possibly cause the structure to crumble. This problem cannot be prevented, however corrosion inhibitors can mitigate its effects. The choice of inhibitor is crucial for environmental preservation. Some rust inhibitors induce harmful exposure, whereas green inhibitors are eco-friendly, contain no toxic compounds, and are reasonably priced. Reinforcing steel corrosion is the most prevalent kind of concrete structure degradation. To prevent corrosion in concrete structures, many forms of corrosion inhibitors have been developed and commercialised. The purpose of this experiment is to determine the impact of inhibitor addition on the strength and durability of Portland Pozzolana Cement (PPC) mortar in a corrosion environment. Study variables include cement type (53 grade PPC), corrosion inhibitor type (sodium nitrite (SN) based and calcium nitrite (CN) based), and corrosion inhibitor dose (1 percent , 2 percent and 5 percent by weight of cement). Tests of compressive strength, splitting tensile strength, flexural strength, and shear strength were conducted to examine the strength qualities. The chloride penetration test is used to assess durability.

KEYWORDS: Corrosion inhibitor; durability properties; strength properties; cement mortar;

I. INTRODUCTION

Reinforced concrete is the most widely used building material in the world. When reinforced concrete structures are exposed to harsh conditions, reinforcement corrosion is the most common kind of damage that can occur. Use of corrosion inhibitors as concrete admixtures is one of the most popular, practical, and cost-effective corrosion prevention strategies currently available. Recent times have seen widespread usage of slag in concrete, either as a distinct cementitious component or as a component of blended cement. It functions synergistically with Portland cement to boost strength, decrease permeability, enhance resistance to chemical assault, and prevent rebar corrosion. In reinforced concrete construction, calcium nitrite and sodium nitrite-based corrosion inhibitors are also widely used. Kim et al. (1) evaluated the inhibitory effect of a calcium nitrite-based corrosion inhibitor using the polarisation technique, as well as the inhibitor's effect on chloride transport, compressive strength, and setting time of concrete. Sideris et al. investigated the effect of a calcium nitrite-based corrosion inhibitor on the corrosion of reinforcing steel implanted in 14 distinct mortars (2). Han-Seung Lee et al. (3) conducted accelerated corrosion testing of reinforcing steel in chloride-containing mortar utilising a lithium nitrite corrosion inhibitor and focused on the nitrite–chloride ion molar ratio as the test parameter. Memon et al. (4) investigated the performance of high workability slag-cement mortar for ferrocement with variable amounts of GGBFS (50 percent and 60 percent) as cement replacement and superplasticizer, with the water cement ratio set so that the flow value is 1363 percent. Shannag et al. (5) investigated high-strength mortar with variable quantities of silica fume, fly ash, and super plasticizer at various water-cement ratios. They produced 21 mortar mixtures and examined their flow properties and development of compressive strength. David Darwin et al. (6) compared the performance of various corrosion inhibiting techniques, including epoxy coating on steel rebars, concrete admixed with calcium nitrite and two other organic inhibitors, bars with primer coating using

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micro-encapsulated calcium nitrite along with epoxy, and zinc coating of reinforcement prior to epoxy application. Using capillary water absorption test, chloride penetration test, and accelerated carbonation test, Haibing Zheng et al. (7) investigated the influence of a surface-applied corrosion inhibitor on the durability of concrete. Daniel Cusson et al. (8) conducted five-year durability studies on concrete exposed to corrosive environments on bridge barrier walls and on accelerated electrochemical cells in the laboratory by employing nine corrosion inhibiting systems, such as concrete admixtures, steel reinforcement coatings, and concrete surface coatings or sealants. According to a survey of the relevant literature, several researchers have examined the effectiveness of calcium nitrite-based inhibitors on the corrosion protection of steel rebars in concrete and mortar. Sodium nitrite and migrating corrosion inhibitors are also of interest to several researchers. To understand the strength and durability performance of slag cement mortar or concrete due to the integration of sodium nitrite and calcium nitrite-based inhibitors, however, few research are available.

II. MATERIALS USED IN THE STUDY

The materials used in the study includes standard sand, cement Portland Pozzolona Cement (PPC), commercially available branded sodium nitrite and calcium nitrite based corrosion inhibitor and water. Mix proportion of cement mortar is 1:3 (1 part of cement: 3 parts sand) and the workability of mortar mix is fixed as 75-90% so that amenable for casting with minimum compaction and without bleeding.

The corrosion inhibitors was added at 1%, 2% and 5% by weight of cement.

Table 1 shows the properties of fine aggregate and Table 2 shows the physical properties of corrosion inhibitors used in the study. Since there is changes in the consistency values of cement due to addition of corrosion inhibitor, mini flow test (9) was conducted to ascertain the flow properties of inhibitor admixed mortar and accordingly water-cement ratio was fixed. Trial and error method was adopted to arrive the water-cement ratio for control and corrosion inhibitor modified mortar with a desired workability. Table 3 shows the different types of mortar and corresponding water- cement ratio for the desired workability.

Table 1 : Properties of Fine Aggregate

Property	Test Procedure	Test Result
Specific gravity	BIS 2386: 1963, “Indian Standard Methods of test for Aggregates for concrete, Part 4 Specific gravity, density, voids, absorption and bulking”	3.03
% Water absorption		1.73
Bulk density		17.6 KN/m^3
Fineness Modulus		3.035
Grading zone	BIS 383 : 1970, “Specification for Coarse and Fine Aggregates from Natural sources for concrete”	Zone - III

Table 2: Physical Properties of Corrosion Inhibitors

Property	Corrosion Inhibitor	
	Sodium Nitrite based	Calcium Nitrite based
Colour	Dark Brown	Pale White
pH	11.58	12.65
Specific Gravity	1.182	1.105

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Table 3: Details of Mortar Mix and w/c ratio as per Mini Flow test

Type of mix	Workability(% flow)	W/C Ratio
PCM	82	0.55
PCM+1% SNI	87	0.50
PCM+2% SNI	79	0.45
PCM+5% SNI	86	0.40
PCM+1% CNI	80	0.50
PCM+2% CNI	89	0.45
PCM+5% CNI	85	0.45

Note : PCM : Portland Pozzolona Cement Mortar; SNI : Sodium Nitrite based Inhibitor; CNI : Calcium Nitrite based Inhibitor

III. EXPERIMENTAL INVESTIGATION

The performance of corrosion inhibitor modified PPC mortar were assessed under strength and durability aspects. The strength related tests conducted includes compressive strength test, splitting tensile strength test, flexural strength test and shear strength test. Durability tests such as chloride ion penetration test is conducted. The compressive strength test was conducted as per BIS 516 (10) in a 500 kN capacity compressive testing machine to find the compressive strength of 70.6mm cube specimen at 7 days, 14 days, 28 days and 56 days of curing period. Split tensile strength test was carried out in a 150 ton capacity compression testing machine as per BIS 5816:1999 (11) and the specimen size is 150mm diameter and 300mm height mortar cylinder, tested at the age of 28 days. The specimens of size 160 x 40 x 40 mm cured for 28 days were subjected to flexural strength test as per BIS 516-1956 (10) in a Universal Wood Testing Machine of 2ton capacity.

For chloride ion penetration test (13), mortar cube specimens of size 70mm x 70mm x 70mm were cast, applied with polymer cementitious waterproof coating on all four sides leaving top and bottom surface. The specimens were kept immersed in 3% NaCl solution for 20 days, split open along uncoated top and bottom surface and sprayed with an indicator solution comprising of 0.1 N Silver Nitrate and 0.1% Sodium Fluorescein. The surface penetrated by chloride turns to white colour and the unaffected area remain in dark grey colour as shown in figure. The depth of penetration of chloride is measured at 8 locations along the periphery and averaged.

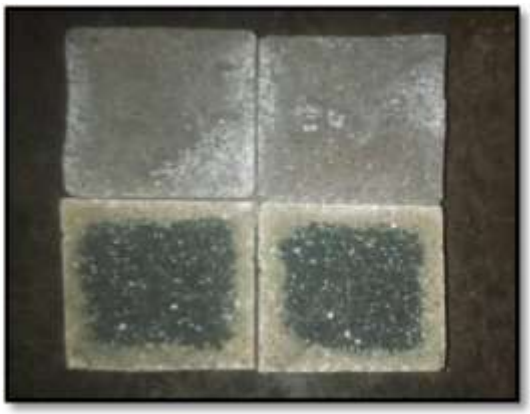

Figure: View of specimens showing Chloride Penetration

IV. RESULTS AND DISCUSSION

The comparison of compressive strength for control and SN inhibitor admixed PPC mortar. It can be seen that inhibitor admixed PPC mortar exhibits increase in compressive strength irrespective of dosage addition and age of test as compared to control PPC mortar. The 7 day compressive strength for PPC mortar admixed with SN based inhibitor at 1%, 2% and 5% revealed an significant increase in compressive strength of the order of 47%, 19% and 70% respectively as compared to control PPC mortar. The similar trend is observed for 14 day compressive strength test results. Whereas marginal increase in 28 day compressive strength of the order of 5%, 9% for inhibitor admixed PPC mortar at 1% and 2% respectively as compared to control mortar. But addition of inhibitor at 5% appreciably increases the 28 day strength of the order of 15% as compared to control PPC mortar.

The comparison of compressive strength for control and CN admixed PPC mortar. It can be seen that addition of CN based inhibitor at 1%, 2% and 5% by weight of cement significantly increases the 7 day compressive strength of the order of 76%, 84% and 92% as compared to control PPC mortar. The similar trend is followed in the 14 day compressive strength test results. But addition of 1% CN based inhibitor marginally increases the 28 day compressive strength of the order of 5%, whereas addition at 2%, 5% significantly increases the compressive strength of the order of 17% and 26% respectively as compared to control PPC mortar.

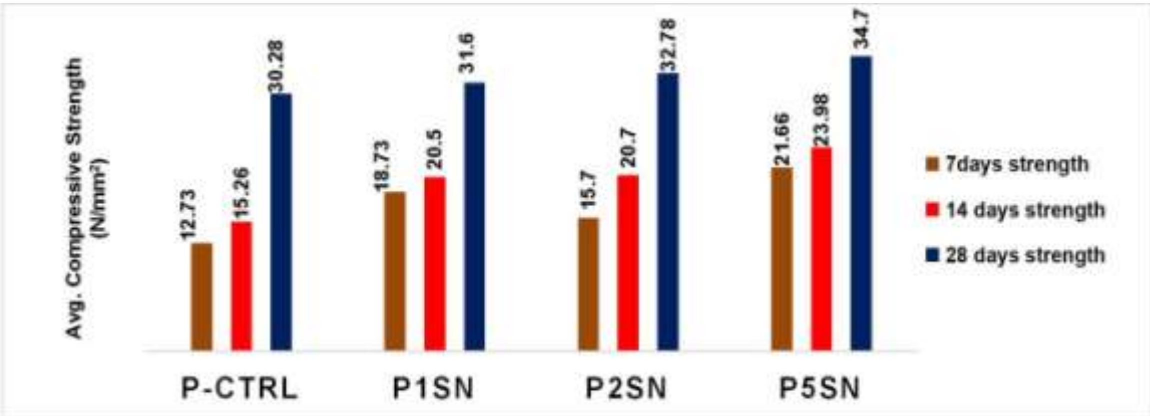

Figure: Comparison of Average Compressive Strength for control and SN inhibitor admixed PPC mortar

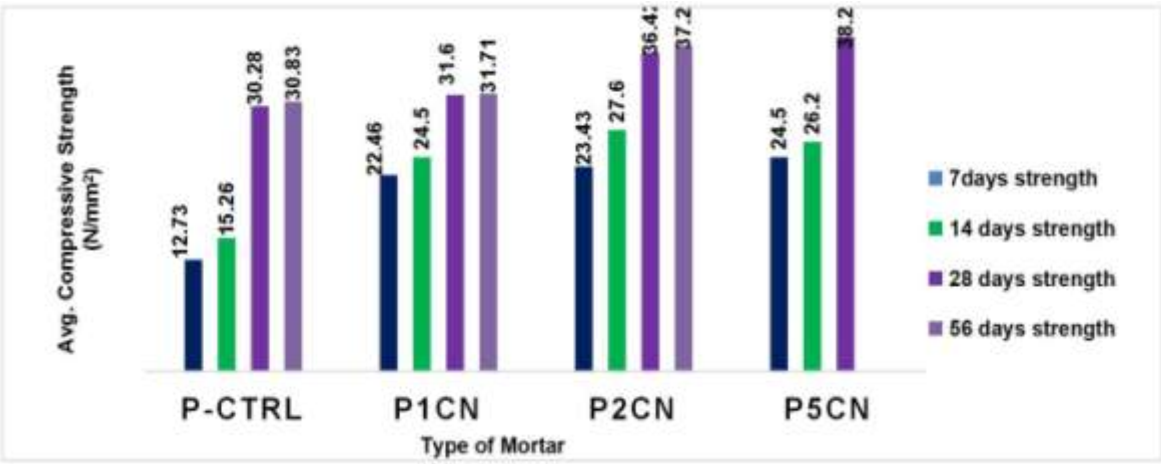

Figure: Comparison of Average Compressive Strength for control and CN admixed PPC mortar

The comparison of splitting tensile strength for control and corrosioninhibitoradmixed PPC mortar. It can be seen that addition of SN and CN based inhibitor inPPCmortarsignificantly increases the splitting tensile strength irrespective of the dosage addition. AdditionofSN inhibitor at 1%, 2%

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and 5% significantly increases the tensile strength of the order of 19%, 36%and 91% respectively as compared to control PPC mortar. Whereas addition of CNinhibitordrastically increases the splitting tensile of the order of 2.04 times and 2.17 times uponinhibitordosage at 1%, 2% respectively as compared to control mortar. Addition at 5%exhibits similar value as that of control mortar.

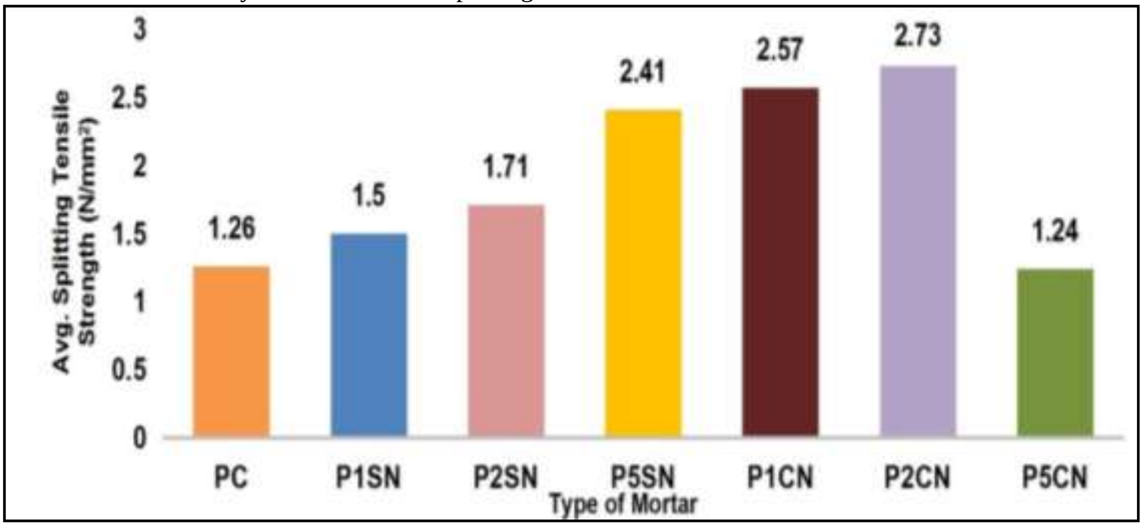

Figure: Comparison of Average Splitting Tensile Strength of Control and Corrosion Inhibitor Admixed PPC Cement Mortar

The comparison of flexural strength of control and inhibitor admixed PPC mortar. It can be seen that flexural strength offered by control PPC mortar is 6.23 MPa which is marginally less than the 1% SN inhibitor admixed mortar. But SN inhibitor modification at 2% and 5% significantly increase the flexural strength of the order of 31-33% as compared to control mortar. Addition of CN based inhibitor also significantly increases the flexural strength of the order 30% irrespective of the dosage levels as compared to control PPC mortar.

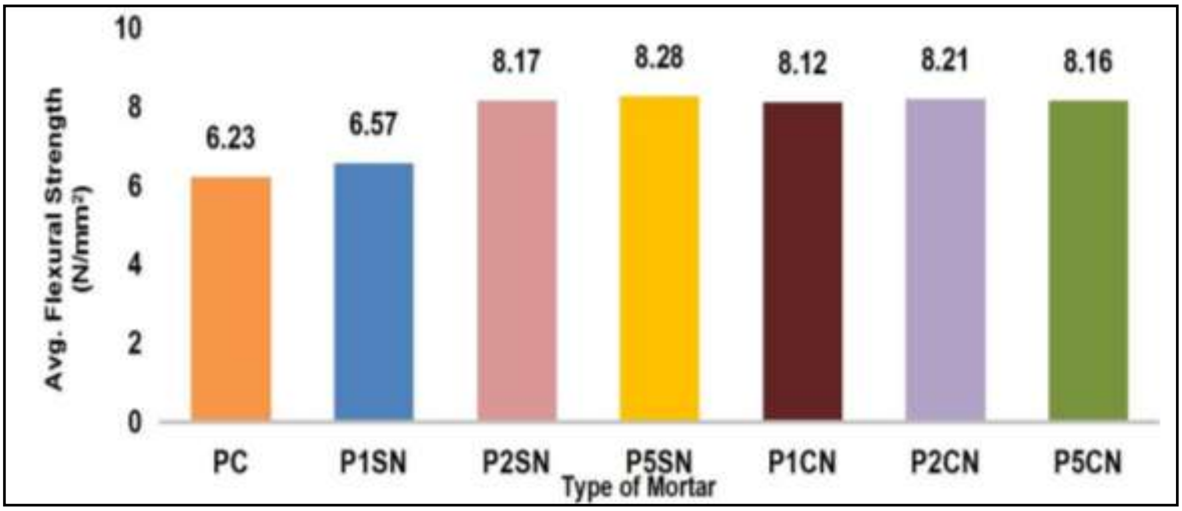

Figure: Comparison of Average Flexural Strength of Control and Inhibitor Admixed PPC Mortar

The comparison of average depth of penetration of chloride ion in the control and inhibitor admixed PPC mortar. Addition of SN inhibitor in PPC reduces the chloride ion penetration in the range 14 - 33% whereas CN inhibitor incorporation in cement mortar offers 10-40% reduction as compared to control mortar. The appreciable durability performance was obtained for SN inhibitor modification at 2% and CN inhibitor modification at 1% as compared to other tested dosages.

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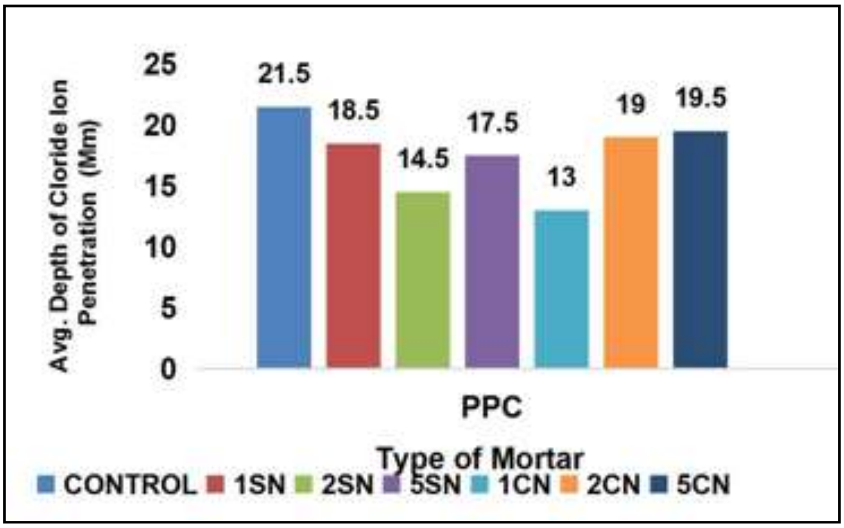

Figure : Comparison of Average Chloride Ion Penetration for Inhibitor Admixed PPC and Cement Mortar

V. CONCLUSIONS

Based on the test results and further analysis following conclusion are drawn:

- The water cement ratio is reduced marginally due to addition of SN based and CN based corrosion Inhibitor for the same workability of control mortar.
- Addition of SN and CN based inhibitor at 1%, 2% and 5% by weight of cement did not appreciably influence the fresh properties of PPC cement such as initial and final setting time but marginal reduction in consistency of cement.
- There is an marginal increase in 28 day compressive strength for SN admixed PPC mortar of the order of 5-15% and CN admixed mortar of the order 5-26% as compared to control PPC mortar.
- Addition of SN and CN based inhibitor in PPC mortar significantly increases the flexural strength of the order of 30% as compared to control PPC mortar.
- Addition of SN inhibitor in PPC reduces the chloride ion penetration in the range 14 - 33% whereas CN inhibitor incorporation in cement mortar offers 10-40% reduction as compared to control mortar.
- It is concluded that addition of sodium nitrite and calcium nitrite based inhibitors enhances the durability properties of PPC mortar without affecting the strength properties.

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