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A Study on the Effect of Anodic and Bipolar Corrosion Inhibiting Admixtures on Strength Parameters of Concrete

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Abstract: ***Corrosion inhibitors in concrete have become a viable solution for controlling the corrosion in concrete structures. However, the effect of the corrosion inhibitors on the strength parameters of concrete is also important. This study examined workability and compressive strength development in concretes mixed with Anodic Inhibitor (Calcium Nitrite based) and Bipolar Corrosion inhibitor. Two types of Concretes made from Portland Pozzolana Cement (PPC) and Ordinary Portland Cement (OPC) and the effect of corrosion inhibitors on the strength parameters are studied.Test results showed that there is no much improvement in workability of OPC concrete mixes or PPC concrete mixes by addition of both types of corrosion inhibitors used in this study. Addition of Calcium Nitrite based inhibitor has resulted in marginal increase of compressive strength of concrete at 28 days, whereas, the addition of Bipolar inhibitor has resulted in marginal decrease of compressive strength of concrete at 28 days.***

Keywords: Corrosion inhibitors, Anodic Inhibitor/ Calcium Nitrite based inhibitor, Bipolar Corrosion inhibitor, workability, compressive strength

1. Introduction

The main cause for deterioration of reinforced concrete structures is the corrosion of the embedded steel, in particular when exposed to marine environments or deicing salts, due to the action of chloride. Deterioration of reinforced concrete structures results from external factors or internal causes within the concrete itself. External chemical attack occurs mainly through the action of aggressive ions, such as chlorides, sulphates or carbon dioxide, as well as many natural or industrial liquids and gases. Corrosion of steel bars is a main factor affecting both the concrete durability and strength. Since the mid 1960's, several methods have been investigated to extend the time to corrosion damage in structures. Methods like epoxy and galvanized coatings of reinforcing steel, active and passive cathodic protection systems, and use of corrosion inhibiting admixtures in concrete have been adopted in the recent times[1]. Cathodic protection systems have been proven to be effective, but requires constant monitoring to ensure effectiveness and, depending upon the application, may be maintenance intensive and expensive to install.[2,3]. Epoxy coating of steel became the corrosion prevention method of choice in the late 1970's [4]. In the recent past, the use of corrosion inhibitors has become more common in preventing or delaying corrosion related damage in reinforced concrete structures [5].

Corrosion Inhibitor is defined as "a chemical substance that decreases the corrosion rate when present in the corrosion system at suitable concentration, without significantly changing the concentration of any other corrosion agent." (ISO 8044- 1989). Corrosion – inhibiting admixtures are mainly used in concrete exposed to seawater or to varying degrees of exposure to aggressive chemical environment. Earlier studies looked at numerous corrosion inhibition admixtures with the most attention focused on sodium nitrite, Potassium chromate, Sodium benzoate and stannous chloride (Saraswathy et al. 2001).

Hence, two commercially available corrosion inhibitors, Anodic inhibitor (Calcium Nitrite based) and Bipolar Inhibitor mixed in concrete made from Portland pozzolana cement (PPC) and Ordinary Portland cement (OPC) are studied in terms of modification of the workability and compressive strength of concrete.

2. Experimental

2.1 Materials

M 35 grade concretes using PPC and OPC were used to assess the effect of corrosion inhibitors in terms of modification of workability and compressive strength of concrete. The properties of each of these materials used in the concrete are tested and used for mix design of concrete. The materials are tested in conformation with the IS code.

The materials used for this experimental work are
1) Cement: Ordinary Portland Cement
2) Cement: Portland Pozollona cement
3) Sand : Zone II
4) Coarse aggregate: HBG 20 mm graded
5) Water: potable water

Admixtures
1) Commercially available Anodic (Calcium nitrate based) corrosion inhibiting admixtures (CNIA)
2) Commercially available Bipolar corrosion inhibiting admixtures (BIA)

2.1.1 Ordinary Portland Cement (OPC) and Pozollona Portland Cement (PPC)

53 grade Ordinary Portland Cement conforming to IS:8112 and Portland Pozzolana Cement conforming to IS:1489–Part-I are used in this study and the test parameters are given in Table 1.

Table1: Physical Properties of Cement

S. No	Test Conducted	PPC	OPC
1.	Consistency	30.0%	28.0%
2.	Initial setting time	135 Minutes	120 Minutes
3.	Final setting time	290 Minutes	185 Minutes
4.	**Compressive strength:**(Average of three results) 28 days	46.0 MPa	62.0 Mpa
5.	FINENESS (by Blaine's air permeability method)	314 m^2/kg	305 m^2/kg
6.	SOUNDNESS (by Le-Chatelier's method)	1.0mm	1.0mm

2.1.2Anodic Corrosion inhibitors

A commercially available Anodic Inhibitor (Calcium Nitrite based inhibitor) was used in this study. This is a chloride free, ready to use aqueous solution of calcium nitrite. Calcium nitrite is an ingredient which reacts chemically to interrupt chloride induced corrosion. Nitrites (Calcium or sodium salt) are anodic inhibitors, they compete with chloride ions for the ferrous ions at the anode to form a film of ferric oxide, Fe2O3.

2.1.3 Bipolar Inhibitor

A commercially available bipolar inhibitor was also used in this study for comparison. The chemical based inhibitor containing molecules in which electron density distribution causes the inhibitor to be attracted to both anodic and cathodic processes. Due to the good quality of its vapour pressure and distribution with the moisture within the concrete, these molecules migrate to the steel and form a monomolecular layer along the reinforcement in concrete. Thus corrosion vis-à-vis micro cell formation is inhibited. The test parameters of the corrosion inhibitors are given in table 2.

Table 2: Test parameters of the corrosion inhibitors

S No	Test Conducted	Calcium Nitrite Inhibitor	Bi Polar Inhibitor
1	Dry Material content (by % weight)	31.78	16.15
2	pH	6.03	8.17
3	Ash content (by % weight)	15.55	17.59
4	Relative density	1.18	1.1
5	Chloride (%)	Nil	Nil

2.2 Mix proportions

M35 grade concretes using PPC and OPC were used to assess the effect of corrosion inhibitors. Based on the properties of the ingredients, the mix was designed for M35 grade of concrete as per IS 10262:2009. The concrete specimens were cast to study the modification of the workability and compressive strength of concrete. The various mix proportions used in this study are given in table 3. The Calcium Nitrite Inhibitor is designated as CN and Bi-polar inhibitor is designated as BI.

Table 3: Details of Concrete mix proportions

S NO	Specimen Combination	Cement	Coarse Aggregate		Fine Aggregate	Water	Inhibitor	Remarks
		KG	20mm KG	12mm KG	KG	Litre	Litre	
1	M35 GRADE CONCRETE WITH (OPC)	360	690	460	710	167	0.00	OPC Control Mix
2	M35 OPC + CN2%	360	690	460	710	159.80	7.20	2% Inhibitor
3	M35 OPC + CN5%	360	690	460	710	149.00	18.00	5% Inhibitor
4	M35 OPC + BI2%	360	690	460	710	159.80	7.20	2% Inhibitor
5	M35 OPC + BI5%	360	690	460	710	149.00	18.00	5% Inhibitor
6	M35 GRADE CONCRETE WITH (PPC)	390	676	482	740	172	0.00	PPC Control Mix
7	M35 PPC + CN2%	390	676	482	740	164.20	7.80	2% Inhibitor
8	M35 PPC + CN5%	390	676	482	740	152.50	19.50	5% Inhibitor
9	M35 PPC + BI2%	390	676	482	740	164.20	7.80	2% Inhibitor
10	M35 PPC + BI5%	390	676	482	740	152.50	19.50	5% Inhibitor

2.3 Tests Conducted

The slump cone test was conducted on all the mixes for both OPC and PPC for determining the workability. Concrete cubes of size 150 x 150 x 150 mm were casted for M35 grade concrete using both PPC and OPC cements. Both the inhibitors viz the anodic inhibitor (Calcium Nitrite based) and the Bipolar inhibitor in dosages of 2% and 5% by weight of cement are mixed in the concrete mixes and cubes were casted. These dosages are adopted based on the literature review and manufacturer's dosage range. The cubes are cured under water and are tested for determining the compressive strength at 3 days, 7 days and 28 days. The Testing of specimens for compressive strength were carried out according to IS: 516-1959in an automatic compression testing machine of capacity 5000 kN.

3. Results and Discussion

Workability: The workability tests were conducted for various mixes are presented in table 4. There is no improvement in workability by addition of corrosion inhibitors in concrete. For OPC mixes, by adding the calcium Nitrite based inhibitor at dosage of 2% has shown a reduction of slump value by about 9% and addition at 5% has shown a reduction of slump value by about 16%. For the Bipolar inhibitor, the slump values are reduced by 23% and 18% for dosages of 2% and 5% respectively.For PPC mixes, by adding the calcium Nitrite based inhibitor at dosage of 2% has shown a reduction of slump value by about 13% and addition at 5% has shown a reduction of slump value by about 19%. For the Bipolar inhibitor, the slump values are

reduced by 24% and 26% for dosages of 2% and 5% respectively.

Table 4: Slump values for various concrete mixes

OPC Mixes	Slump Value (mm)	PPC Mixes	Slump Value (mm)
OPC Concrete	55	PPC Concrete	68
OPC + 2% CN	50	PPC + 2% CN	59
OPC + 5% CN	46	PPC + 5% CN	55
OPC + 2% BI	42	PPC + 2% BI	52
OPC + 5% BI	45	PPC + 5% BI	50

Compressive strength: The compressive strength tests were conducted for various mixes are presented in table 5 .

For OPC Mixes: By addition of 2% Calcium Nitrite inhibitor, there is an initial reduction of compressive strength by 10% at 3 days compared to the control mix. However by addition of 2% Calcium Nitrite inhibitor, there is an increase in compressive strength by 4% and 10% at 7 days and 28 days respectively. For the dosage of 5% calcium nitrite inhibitor, the results are similar compared to that of 2% dosage.By addition of 2% Bipolar inhibitor, there is an initial reduction of compressive strength by 25% and 13% at 3 days and 7 days respectively compared to the control mix. However by addition of 2% Bipolar inhibitor, there is very marginal increase in compressive strength by 2.5% at 28 days. Addition of Bipolar inhibitor at dosage of 5% resulted in the reduction of compressive strength by about 33% to 36%.

For PPC Mixes: By addition of 2% Calcium Nitrite inhibitor, there is a reduction of compressive strength by 11.4% and 9% at 3 days and 7 days respectively compared to the control mix. However by addition of 2% Calcium Nitrite inhibitor, there is a marginal increase in compressive strength by 3.4% at 28 days. For the dosage of 5% calcium nitrite inhibitor, there is a reduction of compressive strength by 13%, 6% and 4.5% at 3 days, 7 days and 28 days respectively compared to the control mix. By addition of 2% Bipolar inhibitor, there is a reduction of compressive strength by 14.6% and 11.2% at 3 days and 7 days respectively compared to the control mix. However by addition of 2% Bipolar inhibitor, there is very marginal increase in compressive strength by 4% at 28 days. Addition of Bipolar inhibitor at dosage of 5% resulted in the reduction of compressive strength by about 10.9%, 7.3% and 3.5% at 3 days, 7 days and 28 days respectively.

Table 5: Compressive strength test results for OPC and PPC mixes

Mix Designation	Compressive strength N/Sqmm		
	3 DAYS	7 DAYS	28 DAYS
OPC Control Mix	24.5	37.4	41.56
OPC + 2% CN	22.1	38.81	45.85
OPC + 5% CN	22.3	38.3	46.37
OPC + 2% BI	18.5	32.59	42.59
OPC + 5% BI	16.4	23.63	43.56
PPC Control Mix	18.5	30.44	42.81
PPC + 2% CN	16.4	27.7	44.44
PPC + 5% CN	16.1	28.52	40.89
PPC + 2% BI	15.8	27.04	44.44
PPC + 5% BI	16.5	28.22	41.33

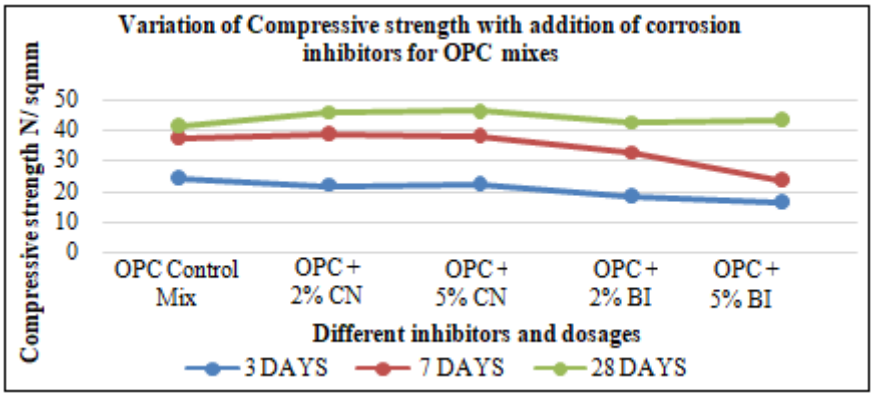

Figure 1: Compressive strength results for OPC mixes

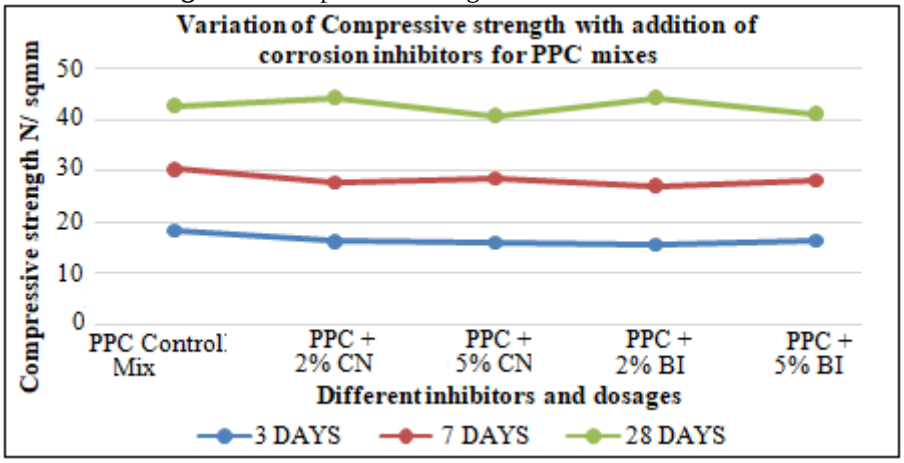

Figure 2: Compressive strength results for PPC mixes

4. Conclusions

There is no improvement in the workability of OPC concrete mixes or PPC concrete mixes by addition of both the Corrosion inhibitors compared to the control mix. The 3 days and 7 days compressive strength result yielded less values compared to the control mix for Calcium Nitrite inhibitor in OPC mixes. However the 28 days result is marginally more compared to the control Mix. The Calcium Nitrite inhibitor has shown improvement in strength properties of OPC mix may be due to the reduction of total porosity of the cement paste by addition of inhibitors.

Addition of Bipolar inhibitor at dosage of 5% resulted in the considerable reduction of compressive strength by about 33% to 36% in OPC mixes. Higher dosages i.e at 5% of Calcium Nitrite inhibitor in PPC mixes has a reduction of compressive strength by 13%, 6% and 4.5% at 3 days, 7 days and 28 days respectively. Bipolar inhibitor at dosage of 5% in PPC Mixes has resulted in the reduction of compressive strength by about 10.9%, 7.3% and 3.5% at 3 days, 7 days and 28 days respectively.

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