Performance Evaluation of Benzimidazole on the durability of Fly Ash Blended Concrete

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ABSTRACT

The use of fly ash is recommended from the point of view of its economy and energy-saving considerations and a critical evaluation of the performance of fly ash should be mainly focused on durability. Among the most pressing concerns for structural concrete durability is the corrosion of the steel reinforcement embedded in concrete. The main aim of this investigation is to study the performances of an organic inhibitor namely benzimidazole, added in various percentages to fly ash blended cement concrete in enhancing its durability without affecting its mechanical and micro structural properties and also determine the optimum percentage of inhibitor to be added for obtaining maximum strength and durability.

KEYWORDS

Concrete, Fly ash, Inhibitor, strength, Durability, Corrosion resistance

INTRODUCTION

It is now universally recognized that the needs of environment protection and sustainability of concrete construction demand that fly ash is not used in landfills or dumped as a waste material but instead utilize the availability of these pozzolanic and cementitious admixtures to enhance the quality of concrete construction[1-4]. Since fly ash can offer a positive, eco-friendly and sustainable cementitious material for the regeneration and rehabilitation of concrete structures, in this study cement is partially replaced with various percentages of fly ash[5-9]. The corrosion of steel reinforcement causes an increase in the volume of oxidized compounds when compared with the volume of the base metal dissolved. Protection of reinforcement from corrosion is provided by the alkalinity of concrete which leads to the passivation of steel[10-13]. National Association of Corrosion Engineers defines inhibitors, as substances which can retard the rate and extent of corrosion, when added to a corroding environment in small concentrations. These inhibitors function by reinforcing the passive layer or by forming oxide layer and preventing chloride ions reacting from it [14-15].This paper is intended on the study of corrosion inhibitor namely benzimidazole, added during casting of concrete in fly ash blended concrete in which cement is replaced by 25% of flyash.The inhibitor was added at the dosage of 1%, 2% and 3% by the weight of cement.

MATERIALS

Ordinary Portland Cement (43 Grade) was used throughout the investigation. In this experiment, river sand with fineness modulus of medium sand equal to 2.06 conforming to grading zone III of IS 383-1970 was used as fine aggregate. Locally available well-graded granite aggregates of normal size greater than 4.75 mm and less than 16 mm having fineness modulus of 2.72 was used as coarse aggregates. Potable water has been used for casting concrete specimen. High yield strength cold twisted deformed bar of Fe 415 graded conforming to IS 1786 has been used. Mechanical properties are, yield strength of 475 N/mm, ultimate tensile strength of 582 N/mm, % of elongation on 30 cm gauge length is 11%. Fly ash was obtained from Mettur thermal power plant in Tamilnadu. In this study, 25% by weight of cement is replaced by class C fly ash. The grade of concrete used is M20 having mix proportion of 1:1.464:3.21 with water cement ratio 0.50.Organic inhibitors were used in this study. Application of these admixtures in reinforced concrete was possible by adding it to the mixing water during concrete preparation. The inhibitor benzimidazole was added at the dosage of 1%, 2%and 3% by weight of cement

EXPERIMENTAL PROGRAM

Experiments were conducted on concrete specimens to study strength and micro structural properties. Strength tests include compressive strength, split tensile strength, flexural strength and bond strength. The micro structural properties studied were percentage of water absorption, percentage of permeable voids and bulk density. To study the migration and dispersion of the organic inhibitors Scanning Electron Microscope (SEM), open circuit potential test, impressed voltage measurement and gravimetric weight loss tests were performed.

RESULTS AND DISCUSSION

Strength test results

Table 1. Strength test results with Benzimidazole (BE)

Sl. No	Specimen	Compressive strength in N/mm2		Split tensile strength in N/mm2		Flexural strength in N/mm2		Bond strength in N/mm2	
		28 days	90days	28days	90 days	28days	90 days	28days	90 days
1	F25	25.91	32.49	2.74	4.65	4.4	9.2	4.22	5.19
2	1% BE	20.68	32.54	1.78	4.71	4.00	9.10	3.79	5.04
3	2% BE	21.76	34.55	1.35	4.10	4.10	9.50	3.95	5.33
4	3% BE	23.21	33.88	1.12	4.93	4.20	9.40	4.02	5.30

Table 1 presents the test values on the 28thand 90th day of compressive, split tensile, flexural and bond strengths for various percentages of benzimidazole inhibitor added.In all the mechanical tests, incorporation of inhibitor enhanced the compressive, split tensile and flexural strengths of the fly ash blended cement concrete.

Micro structural properties

The values obtained from the various micro structural properties tests performed on the hardened concrete specimens with 25% fly ash and with various percentages of the two organic inhibitors are tabulated below.

Table 2. Micro structural test values of 25% fly ash blended concrete with benzimidazole inhibitor

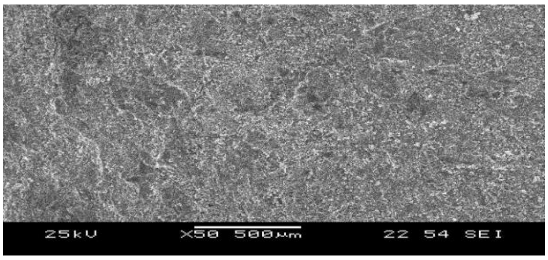
S. No.	Identification	Coefficient of water absorption x 10^{-10} m^2/sec	Percentage of voids(%)	Effective porosity%	Bulk density Kg/m^3
1	FA 25	0.96	0.66	10.06	2404
3	1.0% BE	0.69	0.63	9.94	2426
5	2.0% BE	0.49	0.59	9.85	2433
7	3.0% BE	0.38	0.56	9.73	2444

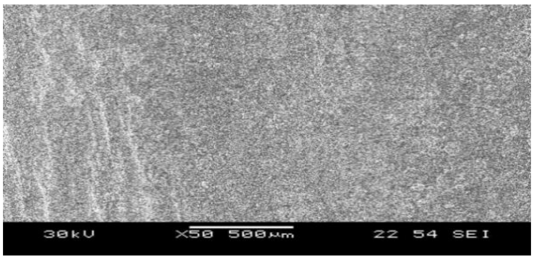
Tables 2 presents the test values for various percentages of inhibitor added.There was appreciable reduction in the porosity and water absorption values for the specimens cast with the inhibitor. This was evident from the picture taken using Scanning Electron Microscope (SEM) shown in Figure. Benzimidazole has migrated effectively through the pores in the concrete, making it impermeable to a larger extent for any foreign element to ingress through it.

Scanning Electron Microscopic analysis

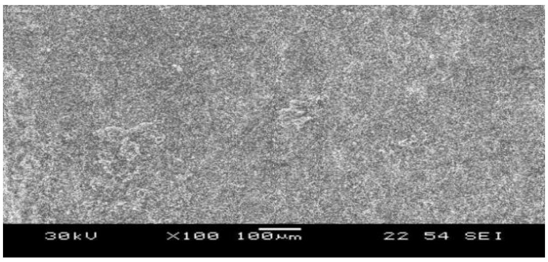
From the following photographs of the scanning electron microscope taken for different dosages of the inhibitor it is obviously seen that benzimidazole inhibitor had effectively diffused through the pores of concrete comparatively and had formed compounds that reduce the permeability and porosity upto 2% of dosage.When the dosage of the inhibitors was increased to 3%, the pictures show that these compounds are not effective.

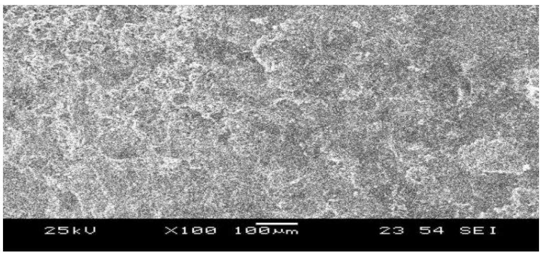
Fig1. SEM photographs





F25 Control – without inhibitor BE -1%





BE – 2% BE – 3.0 %

When the dosage of the inhibitors was increased to 3%, the pictures show that these compounds are not effective.

Open Circuit Potential (OCP) test

The probability of steel reinforcement to corrode was assessed by measuring the Open Circuit Potential (OCP) of embedded steel with respect to standard reference electrode as was conducted earlier for specimens with various percentages of fly ash. Similar specimens were cast with different dosages of inhibitor and their values of corrosion potential were measured between a single half cell and the reinforcement indicating probabilities of corrosion risk.

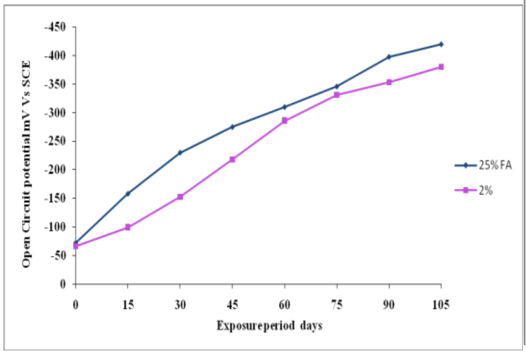


Fig.2 Open Circuit Potential (OCP) test

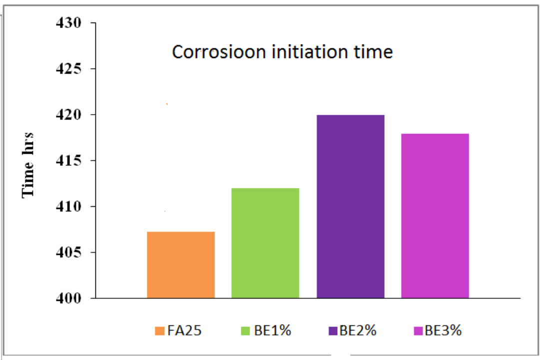


Fig.3 Impressed Voltage Test

Impressed Voltage Test

As carried out earlier for different percentages of fly ash, similar specimens were cast with different dosages of the two organic inhibitors and the test was performed. On applying a constant impressed voltage from a D.C. source, the variation of current was recorded with respect to time. A sharp rise in current indicated the onset of corrosion and cracking of the concrete was usually visible thereafter. The time taken for initiation of first crack was considered as a measure of their relative resistance against chloride permeability and reinforcement corrosion.

Gravimetric Weight Loss Method

The specimens with 1%, 2% and 3% of the inhibitor were broken and the corroded rebars were again immersed in pickling solution, cleaned and weighed. The difference between the initial and final weights were taken as the weight loss of the specimen and it was converted into reduction in thickness and expressed as loss in thickness in mm per year (*mmpy*).

Table 3 Weight loss measurements

S. No.	Identification	Corrosion rate in mmpy
1	FA 25	0.0542
2	BENZ – 1%	0.0301
2	BENZ – 2%	0.0212
3	BENZ – 3%	0.0242

Discussion on test results

The results of all the corrosion tests performed prove that due the decrease in the permeability and porosity of the fly ash blended concrete with increase in dosages of the inhibitors, the ingress of chlorides through the dense concrete medium took more time and hence the corrosion initiation times were increased. With increase in percentage of inhibitors, the corrosion initiation time accordingly increased in the impressed voltage test. The same trend was observed in OCP and weight loss measurement techniques.

Conclusion

It was determined that 2% benzimidazole inhibitor added specimens performed well when compared with other percentages of inhibitor both in strength, micro structural and durability tests. 3% of organic inhibitors though enhanced the corrosion resistance proved inferior in mechanical strengths. Hence 2% has been validated as the optimal dosage to be added in 25% fly ash blended concrete with respect to strength and durability.

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