EFFECT OF BENZOTRIAZOLE CORROSION INHIBITOR IN STRENGTH AND DURABILITY PROPERTIES OF CONCRETE

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Abstract—Technological advances have provided new ways of combating corrosion. Corrosion inhibitors are one means of protection for reinforced concrete structures. The effectiveness of commercially available inhibitor for concrete has been investigated, this study focused on the effects of inhibitor on ordinary concrete and high performance concrete. The strength and durability property of different specimens without and with inhibitors on ordinary concrete and high performance concrete was compared.

*Keywords:*Ordinary Concrete, High Performance concrete, Corrosion, Inhibitor, Strength.

I. INTRODUCTION

Concrete is one of the most versatile, economical, and universally used construction material. It is among the few building materials produced directly on the job by the user. High-performance concrete (HPC) is defined as a concrete meeting special combination of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing, and curing practices.In this study, benzotriazole is used as a corrosion inhibitor. Benzotriazole (BTA) and its derivatives are organic inhibitors known as the best corrosion inhibitors for steel in acid and NaCl media. Benzotriazole and many of its derivatives, form very strong complexes with transition metals and are the most widely used types of corrosion inhibitors.

II. NEED OF THE STUDY

Corrosion has been established as the predominant factor causing widespread premature deterioration of concrete construction worldwide, especially of the structures located in the coastal marine environment. It is desirable to monitor the condition of such strategic structures right from the construction stage by carrying out periodic corrosion surveys and maintaining a record of data. For measurement of the corrosion rate of reinforcing steel in concrete, many electrochemical and non-destructive techniques are available for monitoring corrosion of steel in concrete structures. Corrosion inhibitor is a chemical substance which present in the corrosion system at a suitable concentration decreases the corrosion rate without significantlychanging the concentration of any other corrosive agent.

III. OBJECTIVES OF THE STUDY

1) To study the effect of benzotriazole on fresh concrete (ordinary concrete and HPC).
2) To study the effect of benzotriazole on strength of concrete (ordinary concrete and HPC).
3) To study the effect of benzotriazole on durability of concrete (ordinary concrete and HPC).

IV. EXPERIMENTAL STUDY

In this study, materials used for High performance concrete are

1) Silica fume (4 percent)
2) Ground Granulated Blast Furnace Slag (GGBS) (40 percent)
3) Superplasticisers (2 percent)
4) Benzotriazole – corrosion inhibitor (0.1 percent, 0.2 percent, 0.3 percent, 0.4 percent)

A. *Compressive strength test*

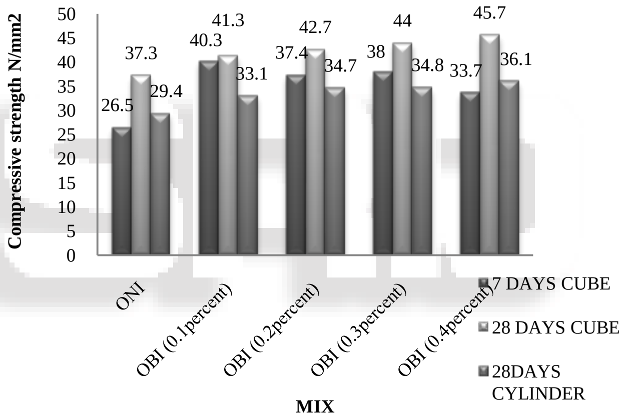

Fig. 1: Compressive strength of ordinary concrete without and with inhibitor

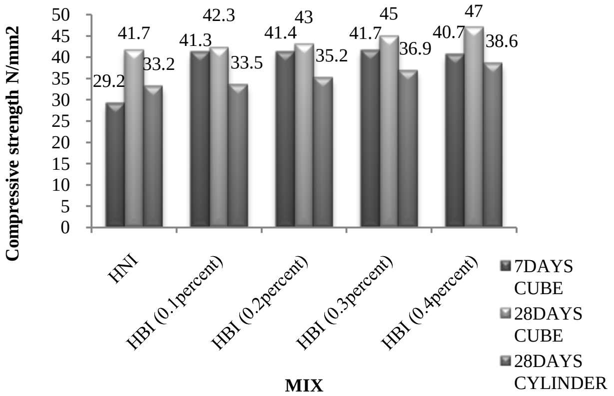

Fig.2: Compressive strength of High performance concrete without and with inhibitor

The compressive strength is measured by breaking cylindrical concrete specimens in a compression testing machine. The compressive strength is calculated from the failure load divided by the cross-sectional area resisting the load.

$\sigma = \frac{F}{A}$ N/mm^2

Where, F = Load applied (N),

A = Area (mm^2).

Compressive strength of concrete specimens is shown in the Fig. 1 and Fig. 2.

B. Split tensile strength test

The test consists of applying a compressive line load along the opposite generators of a concrete cylinder placed with its axis horizontal between the compressive platens. Due to the compression loading a fairly uniform tensile stress is developed over nearly 2/3 of the loaded diameter as obtained from an elastic analysis. The magnitude of this tensile stress is given by the formula

$$T = \frac{2P}{\pi DL} \text{ N/mm}^2$$

Where, T = split tensile strength (N/mm^2).

P = maximum applied load indicated by the testing machine (N)

L= length (mm)

D =diameter (mm)

The test results are given in Fig. 3.

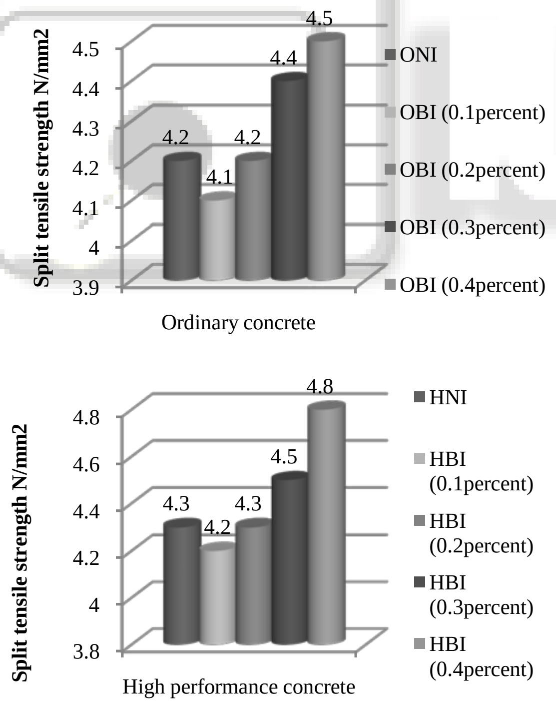

Fig. 3: Split tensile strength of concrete specimens

C. Modulus of elasticity of concrete

The test specimens shall consist of concrete cylinders 150mm in diameter and 300 mm long. Two extensometers are required each having a gauge length of not less than 102 mm and not more than half the length of the specimen. The extensometers shall be attached at the ends, or on opposite sides of the specimen and parallel to its axis, in such a way that the gauge points are symmetrical about the center of the specimen and in no case are nearer to either end of the specimen than a distance equal to half the diameter or half the width of the specimen. The extensometers shall be fixed with the recording points at the same end. The specimen shall be immediately placed in the testing machine and accurately centered. The load shall be applied continuously without shock. Readings shall be taken at each stage of loading and the graph is drawn. From the graph, modulus of elasticity is determined. The stress vs. strain curve is shown in fig 4 and 5.

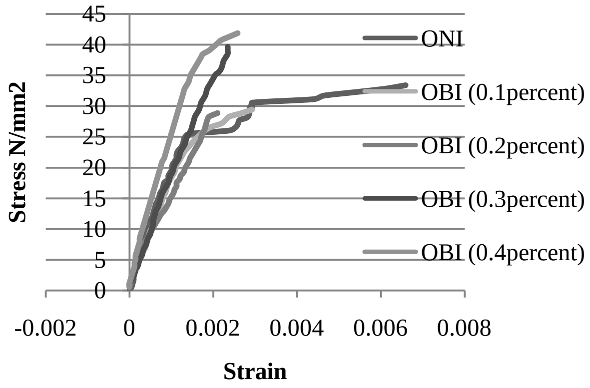

Fig. 4: Stress vs. Strain curve for ordinary concrete without and with inhibitor

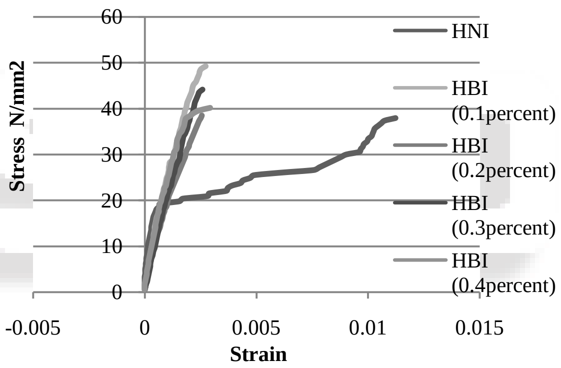

Fig.5: Stress vs. Strain curve for High performance concrete without and with inhibitor

DURABILITY TESTS

D. Water absorption test

According to ASTM C 642-06, Water absorption test was performed on concrete cubes of size 100×100×100mm. After 28 days curing specimens were taken out and dry in an oven at a temperature of 100 to 110°C for not less than 24h. After removing each specimen from the oven, allow it to cool in dry air to a temperature of 20 to 25°C and determine the dry weight. Then the specimens were immersed in water. The wet weights were recorded for every 1/2 hour for $2^{1/2}$ hours, every 1 hour for 4 hours, 24 hrs. 48 hrs. and 72 hrs. The percentage of water absorption was calculated as follow

Percentage of water absorption

$$= \frac{\text{wet weight} - \text{dry weight}}{\text{dry weight}} \times 100$$

Percentage of water absorption graph is shown in Fig. 6

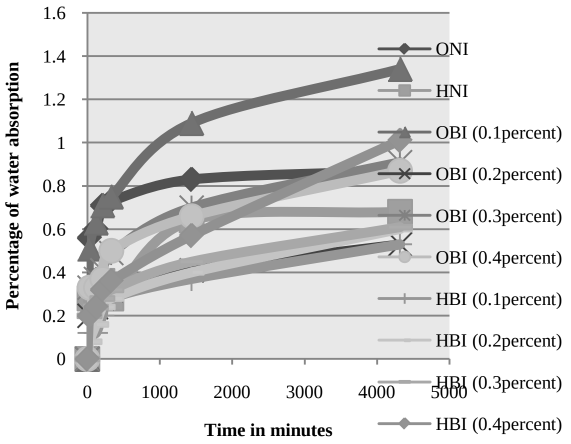

Fig. 6: Percentage of water absorption for concrete specimens

E. Rapid Chloride Permeability Test

According to ASTM C1202 test, a water-saturated, 50 mm thick, 100 mm thick diameter concrete specimen is subjected to a 60 v applied DC voltage for 6 hours using the apparatus and the cell arrangement is shown in Figure 6in one reservoir is a 3.0percent NaC1 solution and in the other reservoir is a 0.3 M NaOH solution. The total charge passed is determined and this is used to rate the concrete according to the criteria included in ASTM C1202.The specimens were fit in the chamber with the required brass as well as rubber oaring. The record time is set as 30 minutes and also the log time as 6 hours and 30 minutes and the current of 60V is passed continuously. The data logger records the readings of corresponding cells at the every record time with its initial readings. At the end of log time, the system halts after taking the final reading. Average current flowing through one cell is calculated by,

Q = 900 * 2 * I Cumulative coulombs.

$I_{CUMMULATIVE} = I_0 + I_{30} + I_{60} + I_{90} + I_{120} + I_{150} + I_{180} + I_{210} + I_{240} + I_{270} + I_{300} + I_{330} + I_{360}$

Where,

Q = Charge passed (coulombs)

I_0 = current (Amperes) immediately after voltage is applied

I_t = current (Amperes) at t min after voltage is applied

The details of the values after testing RCPT specimens are presented in fig 7.

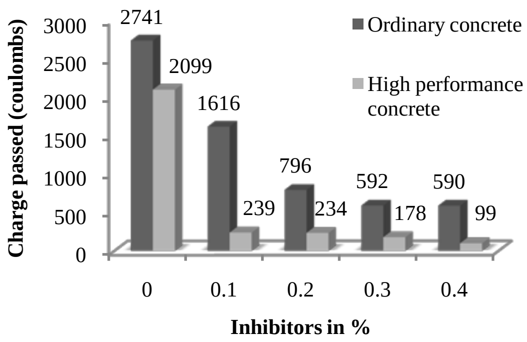

Fig.7: Rapid Chloride Permeability Test results

F. Acid resistance test

Concrete cubes of size 100×100×100mm were cast. After 28 days of curing specimens were dried out and weights (W_1) were noted. The solutions were prepared with various concentrations of HCl (1percent, 4percent) and H_2SO_4 (1percent, 4percent). Then the specimens were immersed in solutions for 30 days. After 30 days specimens were taken out, the weights (W_2) were noted. The percentage of weight loss can be calculated as followsPercentage of Acid absorption

$$= \frac{\text{wet weight} - \text{dry weight}}{\text{dry weight}} \times 100$$

The percentage of weight loss in acid is shown in Fig. 8.

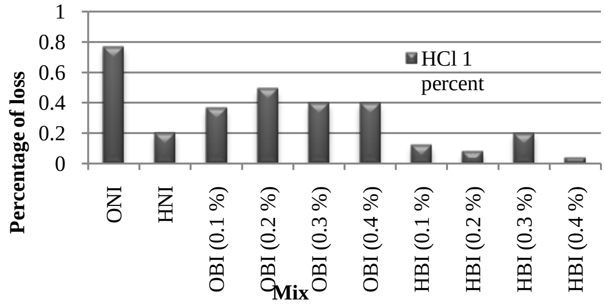

Fig. 8: Percentage of Weight Loss by HCl (1 percent) in concrete Specimens

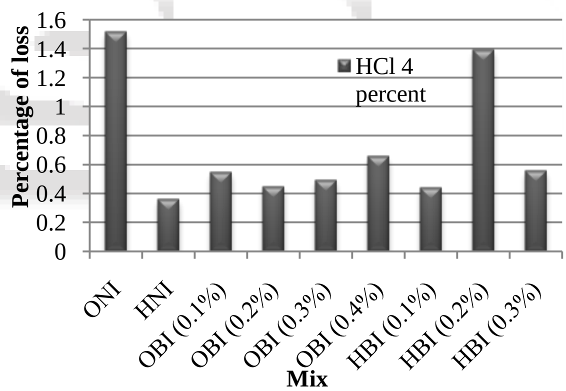

Fig. 9: Percentage of Weight Loss by HCl (4 percent) in concrete Specimens

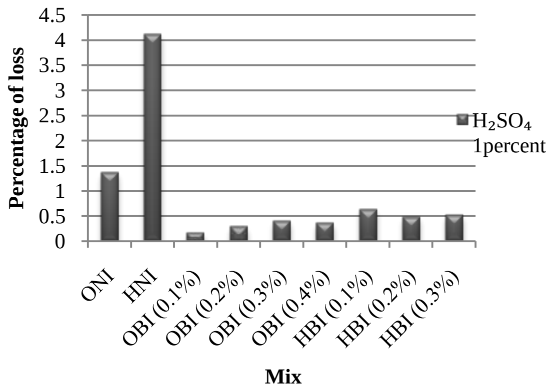

Fig. 10:Percentage of Weight Loss by H_2SO_4(1 percent) in concrete Specimens

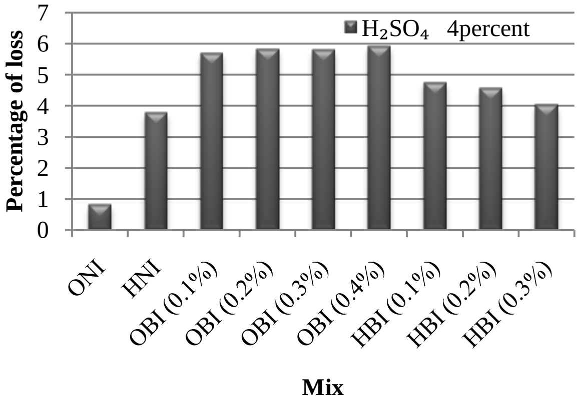

Fig. 11: Percentage of Weight Loss by H_2SO_4(4 percent) in concrete Specimens.

V. SUMMARY AND CONCLUSION

From the experimental studies concerning the strength and durability behavior of inhibitor in concrete, the following conclusions have been obtained

The incorporation of inhibitor as admixture does not show any adverse effects on the strength properties and there was an increase in strength up to certain percentage. Among the various percentages of inhibitor added (0.1percent, 0.2percent, 0.3percent and 0.4percent), the specimens with 2percent addition of benzotriazole show maximum improvement in the mechanical and durability properties when compared with the control specimen which is without addition of any inhibitor. Ordinary concrete with inhibitor shows better results than High performance concrete without inhibitor.

Chloride permeability of concrete with inhibitor shows less permeability of chlorides into concrete when compared with concrete without inhibitor.

The addition of inhibitor as admixture to concrete displays very lower permeability and water absorption.

To conclude, considering strength as well as durability criteria, the optimum percentage addition of inhibitor in concrete is 0.2percent.

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