An Experimental Study on Fly Ash Blended Cement Concrete Structures with Organic (Corrosion) Inhibitor

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Abstract

In this work the effect of organic inhibitor deals with the experimental studies of corrosion resistance properties of fly ash blended cement concrete in R.C.structures with the addition of " Diethanolamine" as Inhibitor in concrete is studied. The inhibitor is added in various percentages of 0.25%, 0.50%, 0.75% and 1% by weight of cement. Inhibitor added in Concrete with correct proportion and proper curing makes a substantial improvement in enhancing the protection of embedded reinforcing steel in concrete from corrosive agents. The various mix proportion used for test are 10%, 20%, 30% and 40% replacement of cement with flyash..

Keywords : Concrete structures, Corrosion, Diethanolamine (Inhibitor)

Introduction

In this work by forming oxide layer and preventing chloride ions reacting with reinforcing.Tests are conducted to study the mechanical properties of the above concrete with various percentages of inhibitor . The tests carried out are Compressive strength test, Split Tensile strength test .

Sodium chloride present in the water used for making concrete leads to corrosion of reinforcement bars in RCC works. In course of time, corrosion continues to reduce the steel reinforcement and weakness the reinforcements. Corrosion of steel bars (rebar) in concrete is a serious problem from both the economic and structural integrity standpoint. Corrosion in reinforced concrete structures can be reduced by bringing down the chloride level in the water used for making.

The following are the main objective of this thesis work :

1. To study the strength, micro structural and corrosion resistance characteristics of fly ash blended cement concrete with 3% addition of Diethanolomine as inhibitor,experimentally and evaluate its performance with that of flyash blended cement concrete without inhibitor.

2. To study the possibility of removal of chloride electro chemically.
3. To study the possibility of removal of chloride by the electro chemical injection of inhibitor into the chloride contaminated concrete.

. The addition of corrosion inhibitor to concrete can increase the protection of the steel. A corrosion inhibitor is a chemical compound added to concrete, to delay corrosion of the steel. This study analyses the performance of the commercially available organic inhibitor on its corrosion control ability and its influence on concrete strength properties. To study the strength, corrosional resistance characteristic of fly ash blended cement concrete with 3% addition of Diethanolamine as inhibitor, experimentally and evaluate its performance with that of fly ash blended cement concrete without inhibitor.

I.Materials and Methods:

The ordinary concrete used in the test program consisted of cementing materials, mineral aggregates and corrosion inhibitor with the following specifications:

- Ordinary Portland Cement
- Graded fine aggregates.
- Graded coarse aggregates.
- Water.
- Organic inhibitor- Diethnolamine
- Fly ash from Thermal power station – Mettur.
- Steel

i. Ordinary Portland Cement:

The cement is a binding material. conforming to IS456-2000-43 grade

ii.Graded fine aggregates:

The materials smaller than 4.75 mm size is called fine aggregates. Natural sand is generally used as fine aggregate. In this experimental work replacement of river sand by quarry waste (fineness modulus of crushed sand equal to 3.2) conforming to grading Zone III of IS – 383 – 1970 was used as fine aggregates.

iii.Graded coarse aggregate:

Locally available well graded granite aggregates of normal size greater than 4.75 mm and less than 16mm having fineness modulus of 2.72 was used as coarse aggregates.

iv.Water:

Potable water has been used for casting concrete specimens. The water is free from oils, acids, and alkalis and has a water-soluble Chloride content of 140 mg/lit. As per IS

456 – 2000, the permissible limit for chloride is 500 mg/lit for reinforced concrete; hence the amount of chloride present is very less than the permissible limit.

v.Steel:

High yield strength cold twisted deformed bar of Fe 415 graded conforming to IS 1786 has been used.

vi.Organic(Corrosion) inhibitors:

The selection of organic inhibitor is more attractive from the point of economy and ease of application. The application of corrosion inhibitor in reinforced concrete is possible by adding it to the mixing water during the concrete preparation or by applying it to the external surface of hardened concrete. The inhibiting compounds should diffuse through the concrete cover and reach the rebar in a sufficiently high concentration to protect steel against corrosion.

vii.Inhibitor in Concrete:

In this method inhibitors are added during casting of concrete. Calcium/sodium nitrites, sodium tetra borate, sodium benzoate, zinc borate are some of the inorganic inhibitors used in concrete. The amount of inhibitor added normally is in the range 10 – 15 ml/m^3 of concrete. According to NACE (National Association of Corrosion Engineers) inhibitors are substances which when added to an environment; decrease the rate of attack on a metal. Corrosion inhibitors function by reinforcing the passive layer or by forming oxide layer and prevent out side agents from reacting with it.

Molecular formula : $C_6H_{15}N$

II.Mix Proportion:

In this study, total of five different mixes were employed to cast specimen, contains all the ingredients of the conventional concrete with design mix ratio of **1**: **1.42**: **3.28** and characteristic compressive strength of 20 Mpa. This control specimen is designated as mix CS. all the other mixes contained classes C fly of fly ash by weight of Portland cement replaced. The proportion of port land cement replaced was 10, 20, 30 and 40 percent and were designated as mix P1, P2, P3 &P4 Respectively. The mix proportions are given in table. For control specimen the w/c ratio is 0.48. The same amount of water is used for all other specimen. The following table shows the mix proportion used for all other specimens. In this study the effect of organic inhibitor – Diethanolamine in concrete is studied. The inhibitor is added in various % of 1%, 2%, 3% & 4% by weight of cement. Inhibitor added in concrete with correct proportions and proper curing makes a substantial improvement in enhancing the protection of embedded reinforcing steel in concrete from corrosive agents. It was designated as mix D1, D2, D3 and D4 respectively.

a. Mix proportions of fly ash

Mix	Cement kg /m³	FA kg /m³	CA kg /m³	Fly Ash kg /m³	Water kg /m³
CS	399.17	567.72	1307.81	-	191.60
P1	359.25	567.72	1307.81	39.92	191.60
P2	319.34	567.72	1307.81	79.83	191.60
P3	279.42	567.72	1307.81	119.75	191.60
P4	239.50	567.72	1307.81	159.67	191.60

FA -fine aggregate, CA – coarse aggregate

b.Mix Proportions of Inhibitors

Mix	Cement kg /m³	FA kg /m³	CA kg /m³	Fly Ash kg /m³	Inhibitor ml	Water kg /m³
CS	399.17	567.72	1307.81	-	-	191.60
D1	359.25	567.72	1307.81	39.92	3.6	191.60
D2	319.34	567.72	1307.81	79.83	6.4	191.60
D3	279.42	567.72	1307.81	119.75	8.4	191.60
D4	239.50	567.72	1307.81	159.67	9.6	191.60

c.Mixing, Compaction and Curing: Good concrete can be obtained only through and uniform mixing, better through and uniform mixing, better through compaction and adequate curing. In the laboratory, the concrete was mixed by hand mixing. All the constituent materials were weighed and dry mixing was carried out for about 5 minutes and then water was added. The mixing was continued till concrete of uniform consistency was obtained / the specimens were compacted using table vibrator. After 24 hours, the specimens were remolded and kept immersed curing tank containing potable water till the required curing period.

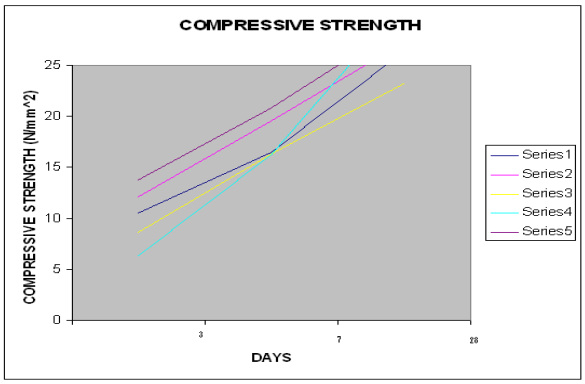
III. Strength Test:

a. Compressive strength

Compressive strength is one of the important properties of concrete. Concrete cubes of size 150 x150x150mm where cast with Diethanolamine and without adding of Diethanolamine (control). After 24 hrs the specimen were demoulded and subjected to water curing. After 3, 7, and 28 days of curing three cubes were taken and allowed to dry and tested in compression machine. The ultimate load at which the cubes failed was noted.

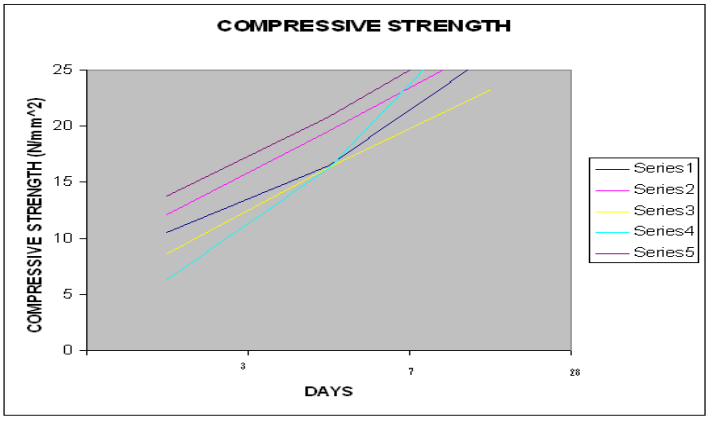
$$\text{Compressive strength (N/mm}^2\text{)} = \frac{\text{Ultimate load}}{\text{Cross sectional area of specimen.}}$$

1.Compressive strength for various mix proportions of fly ash (N/mm^2)



From the figure , it is seen that the strength of the specimen increases with increase in fly ash content up to 30%. But with 40% replacement of fly ash, the strength reduced to the value below that of the control specimen. The mixes with 30% fly ash 16% more compressive strength than the control specimen.

2. Compressive strength with various proportions of fly ash with Diethanolamine Inhibitor (N/mm^2)



Compressive Strength with Inhibitor (N/mm^2)

From the figure, it is seen that mix P3 with addition of 3% inhibitor has shown improvement in compressive strength when compared to the control specimen. The 3% inhibitor having 18% more compressive strength than control specimen.

b.Split Tensile Strength (N/mm^2)

Split tension strength is indirect way of finding the tensile strength of concrete by subjecting the cylinder to compressive force. Cylinders of size 150mm diameter and 300 mm long were cast with Diethanolamine and without adding Diethanolamine (control).

After 24 hrs the specimen were demoulded and subjected to water curing. After 3,7and 28 days of curing the cylinder were taken allowed to dry and tested in compression testing machine by placing the specimen horizontal. The ultimate load of the specimen is at which the cylinder failed.

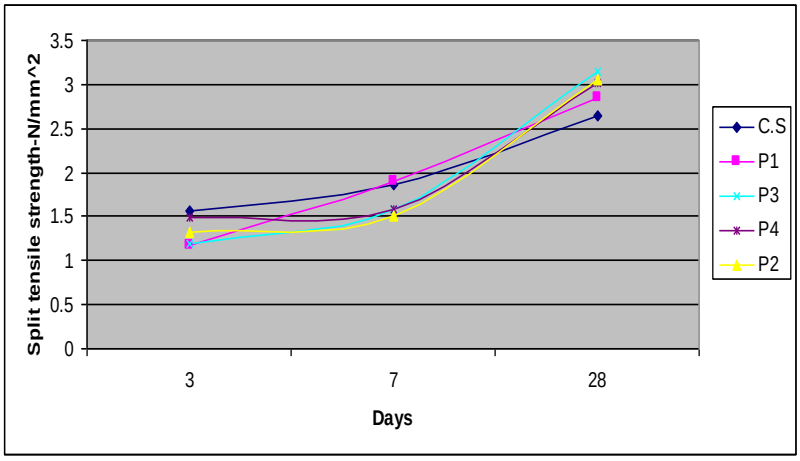
Tensile stress (N/mm^2) =2P / IIdl

And the stress value is obtained in N/mm^2.

P is the ultimate load at which the cylinder fails.

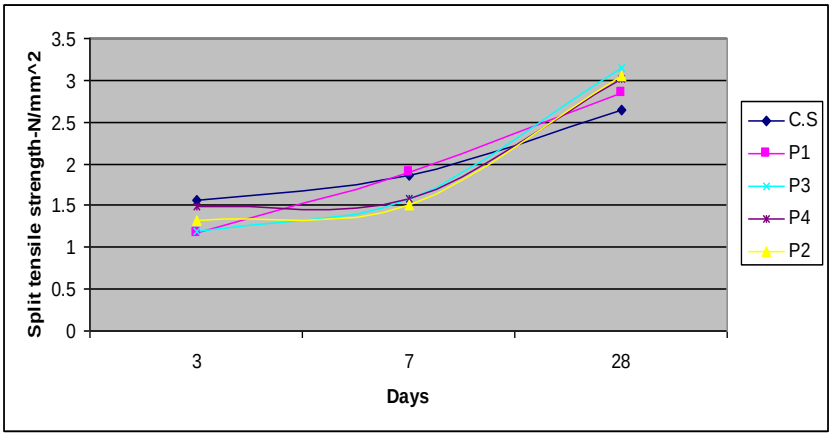
D and L are the diameter and length of the cylinder.

1.Split Tensile Strength for various mix proportions of fly ash (N/mm^2)



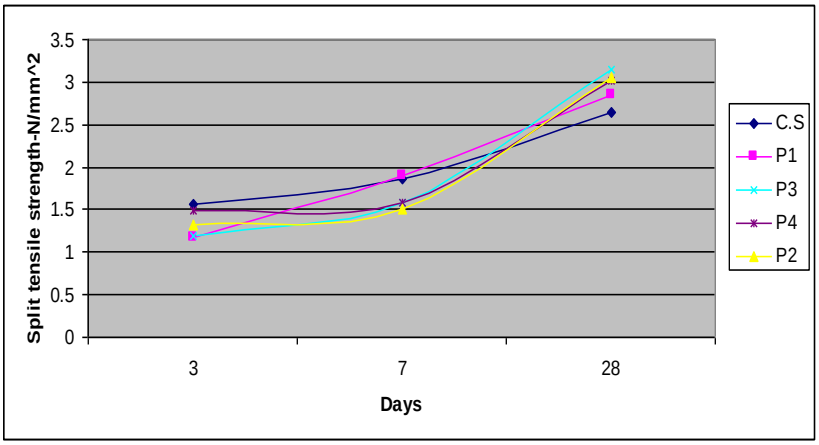
From the figure , it is obvious that all the fly ash replaced specimen have shown increasein strength when compared to control specimens. The mix P3 with 30% fly ash shows1.95% increase in strength more than control specimen.

2. Split Tensile Strength with various proportions of fly ash with Diethanolamine Inhibitor (N/mm^2)



Split Tensile Strength

From the figure , it is seen that mix D3 with addition of 3% inhibitor has shown improvement in Split Tensile Strength when compared to the control specimen. The 3% inhibitor having 2.45% more strength than control specimen.

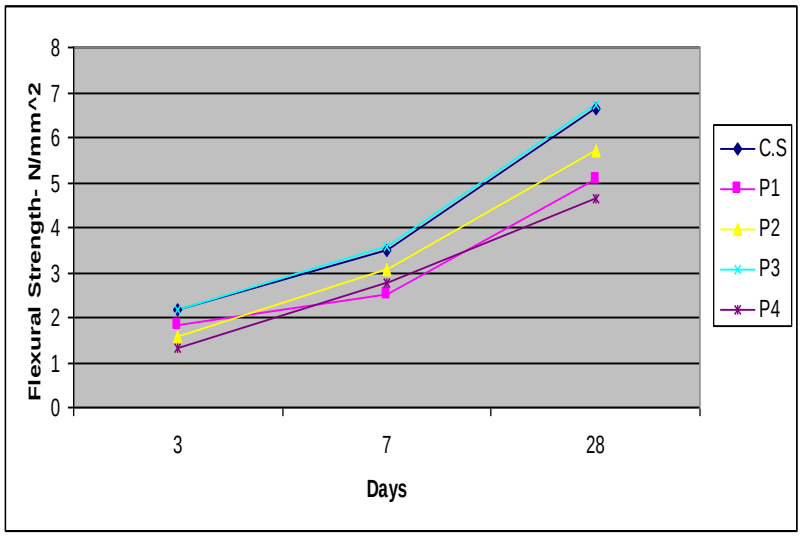


Mix CS has shown the higher value of Split Tensile Strength. Mix P1 has lower value than the control specimens.

3.Flexural strength :

Concrete is relatively strong in compression and weak in tension. Direct measurement of tensile strength of concrete is difficult. Concrete beams of size 100 x 100 x 500 mm are found to be dependable to measure flexural strength property of concrete. The systems of loading used in finding out flexural strength are central point loading and third point loading. The testing machine may be of any reliable type of sufficient capacity for the

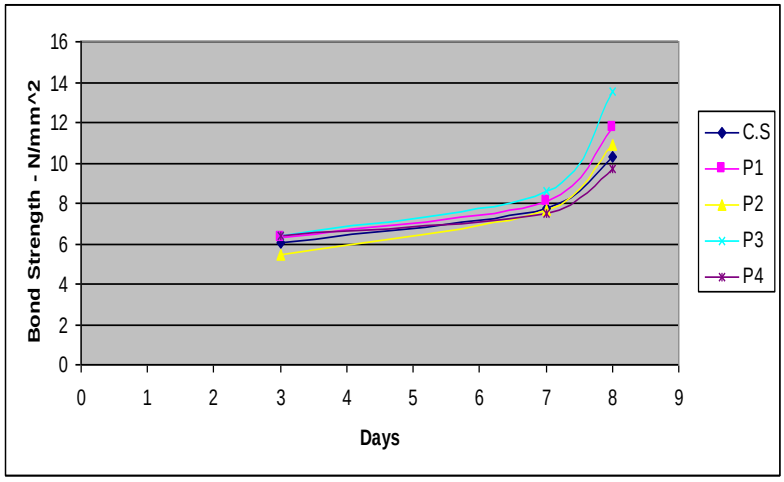
tests and capable of applying the load at the rate specified. Flexural strength is expressed as modulus of rupture and is given by M/Z. M is the maximum moment that the beam can carry Z is the modulus of section. Flexural strength for all the specimens was performed.



Mix P2 has shown nearer strength value when compared to control specimen (CS). Mix P1 & P3 have shown decreased strength. Mix P4 having values lower than the control specimen.

4. Bond Strength :

Bond strength between blending material and steel reinforcement is of considerable importance. A perfect bond, existing between concrete and steel reinforcement is one of the fundamental assumptions of reinforced concrete. Bond strength arises primarily from the friction and adhesion between concrete and steel. Bond strength is mainly dependent on the blending material used in making concrete. The bond strength of concrete is a function of compressive strength and is approximately proportional to compressive strength up to about 20 N/mm2. The blending material used other than Portland cement is fly ash. Its effect on bond strength has been studied for different mixes. Bond strength is given by the formula P/A. Where P is the ultimate load and A is the total area of the rod i.e. Surface area and cross sectional area.



5.Durability Test :

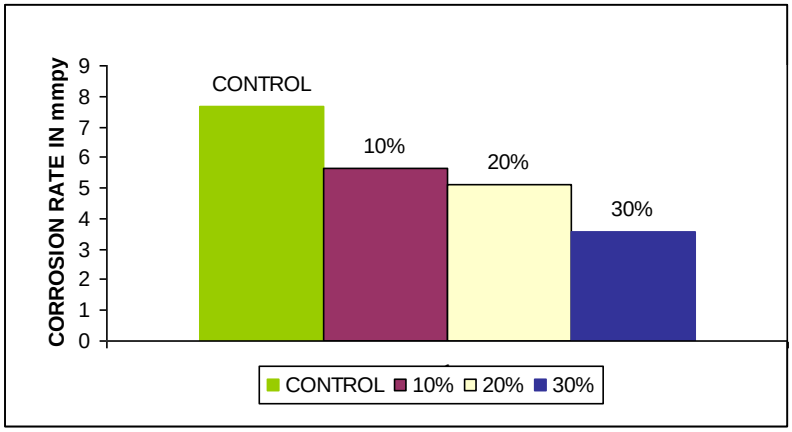
This work is mainly intended in improving the performance of concrete i.e. .it should be durable during its life period. The durability tests performed are

Weight loss rod method.

Further on completion of the test concrete cylinders were taken out for further measurements to determine corrosion rate by weight loss rod method. In the weight loss rod method, Initial weights (W1) of the rods before casting were noted. The specimens were then cast and polarization test was carried out. Corrosion of rod would have taken which will result in cracking of concrete. The specimens tested were then destroyed and the rods were taken. These rods were then kept in a pickling solution. Final weights (W2) of the recovered rods were weighed. Based on the weight loss of the rod (W2-W1) the corrosion rate is determined.

SPECIMENS BEFORE TESTING

SPECIMENS AFTER TESTING



CORROSION RATE

(WEIGHT LOSS ROD METHOD)

Literature Review:

- Zoltanetzky et al, had studied the effectiveness of organic corrosion inhibitors admixtures in concrete. From the literature review, it can be inferred that the electro chemical removal of chloride as well as addition of inhibitors has been done separately to enhance the durability of concrete structure.
- P.Chindaprasirt et al : Influence of Fly Ash Fineness on the Chloride Penetration of concrete. In the Literature Review has said to increased in fly ash, resistance to chloride penetration of concrete is significantly increased.
- Wei sun et-al: Influence of Fly ash Fineness on the chloride Penetration of concrete. Adding fly ash can reduce the corrosion of steel bars.

Conclusion and Results

- The specimens were cast with fly ash of varying percentage of 10, 20, 30 and 40 by weight of cement and for the optimal percentage Diethanolamine inhibitor of varying percentage of 1%, 2%, 3% and 4% weight of cement are added.
- The specimens cast with fly ash have shown better performance in strength tests. The compressive, split tensile strength of the concrete specimen cast with 30% fly ash attained the maximum values. It was observed that there was 16% increase in compressive strength, 2.45% increase in split tensile strength, 13% in flexural strength and 24.5% increase in bond strength.
- For the 30% replacement of cement with fly ash is added various percentages of diethanolmine inhibitor and it is observed that 3% added inhibitor attained the maximum values. It was observed that there was 18% increase in compressive strength,22% increase in split tensile strength and 4% increase in bond strength.
- The weight loss rod method proves that increase in inhibitor percentages decreases the corrosion rate. The specimen with 3% inhibitor has shown a decrease in weight of only 26% when compared that of control specimens.

Discussion and Future Scope

A corrosion inhibitor is an admixture that is used in concrete to reduce the corrosion of rebar. Both organic and inorganic type of inhibitors is widely used in concrete. This has been considered as one of the most cost-effective solutions to the wide spread corrosion problem due to their convenient and economical application to both new structures and repair of existing buildings.

Behavior of higher grade of concrete specimens could be studied. Different corrosion inhibitor can be used hence the change in properties can be studied. The percentage of inhibitor types adding to the concrete may vary. Fly ash, quarry dust, silica fume, slag or combination of these can be used as a part replacement of cement and their properties can be studied.

References:

1. V.M Malhotra and A.A Ramezanianpour (1994) "FLY ASH IN CONCRETE". Canada center for mineral and Energy Technology (CANMET), Sep 1994.

2. Sushi Kumar. Use of fly ash as Fine aggregate in concrete M.tec thesis Delhi college of Engineering 1992.

3. Tarun.R, Naik. Shiw Singh. And Bruce Ramme," Mechanical properties and durability of concrete made with blended fly ash" ACL materials journal, august 1998 pg 454 – 462

4. Syed Ehtesham Hussein and Reaheeduzzafar "corrosion resistance performance of fly ash blended cement concrete" ACI Journal June 1994 : pg 264 -272

5. Salta MM. In: Swami RN, editor "Influence of fly ash on chloride diffusion in concrete" vol.2 Sheffield academic press: 1994 pg 794 -804

6.. ROBERTS M.B ATKINS CP HOGG. V and MIDDLE TON.C a proposed empirical corrosion model for reinforced concrete Proc. Institution Civil Engineers structs&bldge.2000.40 no.1.1 -12

7.A.R.Santhakumar-Concrete Technology- Oxford University press.-ISBN0-19-567153-8

8. Corrosion behaviors of steel in concrete – and over view K.Ganesh Babu, Allagapa Chattier College of Engineering & Technology, karikudi .