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Experimental Study of Strength and Corrosion Resistive Property of Fly Ash Concrete with Inhibitors

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Abstract - **The present study describes the behavior of concrete as well as fly ash concrete when subjected to varying number of high temperature heating cycles. A Concrete mix (1:1.5:3) with 320 kg/m^3 cement and *w/cm* ratio 0.55 was prepared. Cement was replaced by varying percentages (10%, 20%, 40%, 50% and 60%) of fly ash by weight of cement. The concrete was subjected to a constant temperature of 200°C for 7, 14, 21 and 28 heating cycles. One heating cycle corresponds to 8 h heating and subsequent cooling in 24 h. From the literatures it is to be noted that fly ash can be used as partial replacement of cement and in production of lightweight aggregate. Concrete grade considered for experimental study is M20 with 43 grades OPC. Binding material used for concrete is cement with percentage replacement of fly ash as 10% to 50%. 20mm angular granite broken stones conforming to single size aggregate as IS 383-1970 is used as coarse aggregate. The annual consumption of concrete is about fifteen billion tone annually. At the same time abundant quality of fly ash from thermal power plants are being thrown out as waste which creates severe ecological problems and requires larger storage area. The experiment will comprise of strength and durability study on concrete with high volume fly ash. Half-cell potential measurements are simple, inexpensive and virtually non-destructive techniques to assess the corrosion risk of steels in concrete. However, the negative potential area on the equipotential contour map corresponds to high chloride content and localized corrosion. The measured values of the half-cell potential fluctuate due to several factors: the temperature, the type of reference electrode, and the pre-wetting time.**
Keywords: **Corrosion, Resistive Property, Fly Ash, Concrete, Inhibitors**

I. INTRODUCTION

Concrete is a mixture of cement, sand and coarse aggregate. When the concrete is used along with reinforcement they are called as reinforced cement concrete. Steel rods are mostly used as reinforcement because of its easy availability and ductility. Steel rod has a tendency to get corrode when exposed to atmosphere. The atmospheric agent like moisture, air accelerates the corrosion and as a result oxidation film appears on it. These rods when used in concrete it gets oxidized due to its atmospheric condition and corrosion will occur with age of concrete. To prevent this corrosion, corrosion inhibitors are used. The corrosion inhibitors are of two types namely anodic and cathodic. The cathodic inhibitors are used and it forms a film on the steel rod and it prevents oxidation. Inhibitors can be used in two forms as

1. Directly applying the inhibitors on steel rod.
2. Mixing inhibitors with concrete.

Fly ash is comprised of the non-combustible mineral portion of coal consumed in a coal fueled power plant. Fly ash particles are glassy, spherical shaped “ball bearings” typically finer than cement particles that are collected from the combustion air-stream exiting the power plant. The main benefit of fly ash in concrete is that it not only reduces the amount of non-durable calcium hydroxide (lime), but in the process converts it into calcium silicate hydrate (CSH), which is the strongest and most durable portion of the paste in concrete. Fly ash also makes substantial contributions to workability, chemical resistance and the environment.

Fly ash is a finely divided residue resulting from the combustion of pulverized coal and transported by the flue gases of boilers fired by pulverized coal. It is available in large quantities in the country, as a waste product, from a number of thermal power stations and industrial plants using pulverized coal as fuel from boilers.

A. Specific Gravity of Fly Ash-2.30

Fly ash in concrete as partial replacement of cement entails economical, technical and energy saving benefits. To ascertain its technical feasibility in concrete production, a study on its workability and various strengths is needed.

II. OBJECTIVES

The investigation aims at,

1. To arrive a mix design summary for concrete using trial and error method.
2. To study the various strengths of hardened concrete such as compressive strength of concrete cubes at 7 days, 14 days and 28 days.
3. To study the behaviour of high volume fly ash concrete.
4. To study the strength and durability characteristics of fly ash concrete replaced concrete with corrosion resistance inhibitor.

III. REVIEW OF LITERATURE

In India, more than 70 thermal power plants are the source of fly ash. More than 110MT of coal is used annually and 40MT of fly ash is produced every year. If used their disposal needs 28,300 hectares storage land, which may further cause severe ecological problems. Fly ash may be utilized in production of concrete in many forms such as cement clinker in manufacture of cement as cementitious material for partial replacement of sand and as coarse aggregate by making sintered of fly ash aggregate.

H. Saricimen *et al.,* (1961) had invested the "Effectiveness of concrete inhibitors in retarding rebar corrosion". The effect of inhibitors on the corrosion of steel reinforcements in concrete was evaluated by using anodic polarization.The effectiveness of the inhibitors in retarding reinforcement corrosion in the contaminated concrete specimens was evaluated by measuring the corrosion potentials and corrosion–current density. Results indicated that the time-to-cracking in uncontaminated concrete specimens incorporating inhibitors M2 and R2 was higher than that in the control concrete specimens.

S.S. Reshi *et al.,* (1963) the article reports investigation carried out at the Central Building Research Institute, Roorkee, on samples off fly ash obtained from Bokaro, Durkapor, and Madras to assess their suitability for use as pozzolana, as admixtures, or as fine aggregate in mortar and concrete. All the fly ashes are found suitable for use as pozzolana replacing 20 or 25 % of cement whilst none is suitable for the use as admixture. The fly ashes can also by advantageously used to replace sand in mortar and concretes, thereby saving substantial quantities of cement.

Velu Saraswathy *et al.,* (2003) Reinforced concrete is protected from corrosion due to the high alkalinity existing in the concrete environment and the cover concrete which acts as a protective barrier to the access of chloride ions. Apart from this, reinforced concrete structures when exposed to severe marine environments lead to the premature failure of the structure Corrosion of embedded steel in concrete is one of the major causes of premature deterioration of concrete structures which affects the service life of the important structures in the chloride prone environment. Therefore, the chloride permeability plays a significant role in determining the service life of the major infrastructures.

Arivazhagan *et al.,* (2011) Conducted a peculiar study on the environmental benefit with fly-ash stated that there is increases in crop yields and nutrient uptake due to release of major secondary and micro nutrients from fly-ash applied in the soil during crop growth. Basically fly-ash has slightly acidic in pH and its effect is more pronounced in soils having high pH.

Philip L. Owens *et al.,* (1979) explained that the ability of any fly ash to change the properties of a fresh concrete by reducing the water demand is a function not only of the particulate materials but also of mixing. Concrete containing fly ash is deceptive in that it appears less workable then its Portland cement counterpart because of the grater fines volume and the similar water volume, which has an increased effect on mobility when compaction energy applied. Fly ash has slower pozzolanic reaction and does not contribute significantly to strength much before 10 to 14 days. Fly ash used as pozzolana gives durability, lower permeability, greater sulphate and acid resistance and reduced alkali aggregate reaction.

Vinod Goud *et al.,* (2016) This research concludes the study of the effect of fly ash on the properties of concrete for nominal mix of M25 grade of concrete are the Slump loss of concrete increases with increase in w/c ratio of concrete.For w/c ratio 0.35 without any admixtures, initial slump cannot be measured by slump cone test as it is very less. Ultimate compressive strength of concrete decreasing with increase in w/c ratio of concrete. Slump loss of concrete goes on increasing with increase of quantity of fly ash. The 10% and 20% replacement of cement with fly ash shows good compressive strength for 28 days. The 30% replacement of cement with fly ash ultimate compressive strength of concrete decreases.

IV. METHODOLOGY

The Material properties were determined at first, the specimen type and size of mould for testing are listed. The materials that are used water, F.A, C.A, Cement, Fly ash, inhibitors. Fineness test, consistency test, setting time, specific gravity, impact value, abrasion test were carried out for materials and casted after curing testing of specimen and corrosion test were adopted for ascertaining hardened concrete properties.

V. MATERIALS AND MIX PROPORTIONS

The materials for production of CRP of fly ash concrete with inhibitors includes ordinary Portland Cement, Coarse & fine aggregate, water, inhibitors and fly ash. Fly ash was obtained from mettur thermal Power Plant.

Corrosion inhibitor is a chemical juice compound or crystalline solid that, when added to a fluid or gas, decreases the corrosion rate of a metal or an alloy inhibiting either the oxidation or reduction part of the redox corrosion system (anodic and cathodic inhibitors), or scavenging the dissolved oxygen. Examples of an anodic inhibitor are chromate, pertechnetate, Nitrite, and zinc oxide, which forms a passivation layer on aluminum and steel surfaces which prevents the oxidation of the metal. Examples of cathodic inhibitor are zinc oxide, mono ethanol amine, diethanol amine and tri ethanol amine.

Compressive strength test, tensile strength test, and split tensile strength tests were conducted by varying the concentration of inhibitors. The addition of inhibitors not only increased the compressive strength of the concrete but also improved the corrosion resistance properties.

Cement
Specific gravity : 3.15
Brand : OPC 53 grade.
Course Aggregate
Size : Passing through20mm and retaining on 12.5mm sieve
Specific gravity : 2.68
Fine modulus : 3.926
Type : Crushed granite (angular)
Fine Aggregate
Size : Passing through 4.75mm
Specific gravity : 2.68
Fineness modulus : 2.91
Grading zone : I
Fly ash
Specific gravity : 2.37
Water
Ordinary potable water free from impurities.

TABLE I MIX PROPORTION OF 1M^3 CONCRETE

S. No.	Grade of concrete	% of Fly ash in cement	% of Inhibitors	W/C Ratio	Quantities of materials required in Kg/m^3					Mix proportion (C:FA:S:C.A)
					Cement	Fly ash	Sand	C.A	Water (in liters)	
1	M20	-	-	0.5	383.16	-	572.27	1185	191.58	1 :00:1.5:3.0
2	M20	10	1	0.5	344.84	38.31	572.27	1185	191.58	1:0.1:1.6:3.43
3	M20	20	2	0.5	306.52	76.63	572.27	1185	191.58	1:0.24:1.8:3.8
4	M20	30	3	0.5	268.21	114.92	572.27	1185	191.58	1:0.42:2.13:4.4
5	M20	40	4	0.5	229.89	153.26	572.27	1185	191.58	1:0.6:2.48:5.15
6	M20	50	5	0.5	191.58	191.58	572.27	1185	191.58	1:1.0:2.9:6.18
7	M20	60	6	0.5	153.26	229.89	572.27	1185	191.58	1:1.5:3.73:7.73

TABLE II SPECIMENS CASTED

Type	Size	No. of specimen
Cube (solid)	150 x 150 x 150 mm	21
Cylinder (solid)	Dia – 150mm Height – 300 mm	4
Total		25 Nos.

TABLE III COMPARISION OF TEST RESULTS

Grade of concrete	% of fly ash in cement	% of inhibitors added	Cube compressive strength N/mm^2		
			7th day strength	14th day strength	28th day strength
M20	-	-	13.70	17.60	20.20
M20	10	1	13.90	18.70	23.20
M20	20	2	14.10	19.30	23.40
M20	30	3	14.30	19.60	23.70
M20	40	4	14.80	20.80	24.10
M20	50	5	15.20	21.90	25.20
M20	60	6	14.90	21.60	24.80

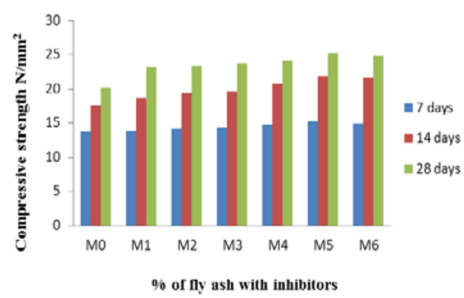

Fig. 1 Cube Compressive Strength

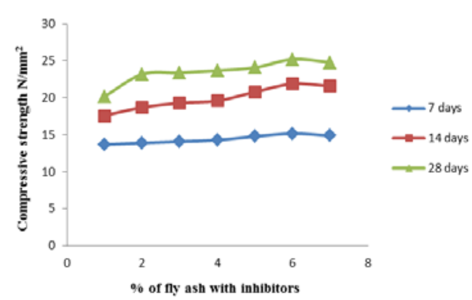

Fig. 2 Cube Compressive Strength

VI. CORROSION

Corrosion is the deterioration of materials by chemical interaction with their environment. The term corrosion is sometimes also applied to the degradation of plastics, concrete and wood, but generally refers to metals Anodic & Cathodic Reactions. Corrosion is a three step electrochemical reaction in which free oxygen in the water passes into a metal surface a one point (referred to as the cathode) and reacts with water and electrons, which have been liberated by the oxidation of metal at the anode portion of the reaction at another spot on the metal surface. The combination of free electrons, oxygen and water forms hydroxide ions. Common problems arising from corrosion are reduction in heat transfer and water flow resulting from a partial or complete blockage of pipes, valves, strainers, etc. Also, excessive wear of moving parts, such as pump, shaft, impeller and mechanical seal, etc. may resist the movement of the equipment. Hence, thermal and energy performance of heat exchange may degrade.

A. Corrosion Test

Corrosion of steel embedded in concrete is an electrochemical process that involves the formation of electrical circuit between areas of active corrosion (anode) and passive areas (cathodes). In corrosion process, the concrete acts as electrolyte allowing the flow of ions from anode to cathodes. In some cases the high pH coating will break down in presence of chloride (or) over time due to exposure of concrete to carbon dioxide. So in order to avoid corrosion due to chloride ions, an inhibitor called phenylenediamine which is a white crystalline solid is added to concrete which prevents the rod from chloride ions by acting as thin film over the rod.

The process involves the electrolytic solution of (copper sulphate) $cuso_4$, multimeter. In this cathode possess the (-ve) charge and anode possess the (+ve) charge. The device applies a current to a given section of reinforcing steel and measures the corresponding increases in the multimeter. The test is called as half-cell potentiometer test.

In this process the reinforced concrete kept for curing taken for testing. A beaker with porous at its bottom is filled with $cuso_4$ solution and a sponge is kept below the porous of beaker and a copper electrode is kept inside the beaker where it is connected negative terminal of multimeter and the positive terminal to the reinforcement rod. Now the beaker fixed with sponge is kept on the concrete and $cuso_4$ solution, passes through the porous of beaker into the sponge and slowly penetrates into the concrete and as soon as it reaches the reinforced rod ionic reaction takes place as explained above the processes is done at five different place on the concrete to get an average reading in the multimeter.

B. Corrosion Result

The following figures show the results of corrosion.

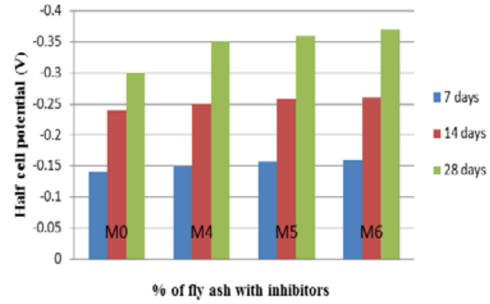

Fig. 3 Corrosion Results

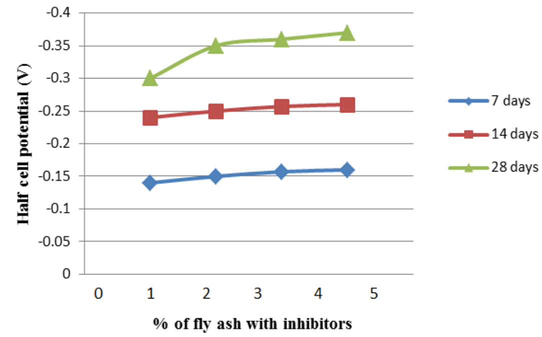

Fig. 4 Corrosion Results

C. Control Techniques

The principle methods to prevent or minimizing corrosion include

1. Selecting suitable materials of construction to resist corrosion
2. Adding protective film- forming chemical inhibitors that the water can distribute to all wetted parts of the system.
3. Controlling scaling and micro-biological growth.
4. Protect cathodically, using sacrificial metals.
5. Apply protective coatings such as paints, metal plating, tar or plastics on external surfaces.

VII. CONCLUSION

From the experimental results proposed in the given project, the following conclusions may be arrived

1. With the use of inhibitors, half the replacement of cement with fly ash results in higher compressive strength. Though when the fly ash is replaced more than 60%, the compressive strength does not show further increase in strength of concrete.
2. Use of inhibitors increases the workability of concrete and reduces the water consumption.
3. It is highly economical.
4. Factors, such as the temperature, the type of reference electrode and the pre-wetting time. However, the potential gradient remains at the same pattern on the whole of the structure.
5. The evaluation of corrosion by means of the traditional half-cell potential technique using the existing standards may lead to mistakes in cases where the

concrete is water saturated, carbonated and also exposed to the very low temperature.

VIII. FUTURE SCOPE

1. We found the decreases of ionic content only for 28 days which is an approximate value.
2. So the minimum time of 1 year is needed to get the accuracy of decreases in ionic content.
3. Additional test can be done after 1year by weight rod loss method along with half-cell potentiometer test.
4. From the result, we can say that this type of combination is used where the water contains more salt content in case of sea side construction.
5. Inhibitors which are of high value in cost cannot be used by small construction groups.
6. So they are used for constructing the momentorial structures which will be having long life time duration than using normal concrete combination.

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