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Durability Performance of Concrete Replaced with Pond ash as Fine Aggregate

Sreelakshmi R, Reshmi P R
M.Tech Student, Civil Department, SNGCE, Kadayiruppu
Asst. Professor, Civil Department, SNGCE, Kadayiruppu

Abstract: *An increased demand for river sand as fine aggregate in the construction industry has resulted in the reduction of resources and an increase in cost. Under such circumstances, the pond ash which is a residue and by-product of thermal power plant can be used as an economic alternative to the natural sand. This paper deals with the strength and durability performance of concrete replaced with pond ash as fine aggregate and also the effect of integral type inhibitor namely triethanolamine is carried out. The percentage of pond ash added by weight of fine aggregate was 0,10, 20, 30, 40, 50 and that of triethanolamine was added at the percentages of 1%, 2%, 3%, 4%, 5% by weight of cement. The corrosion resistance was evaluated using different electrochemical techniques like Rapid Chloride Penetration Test, Impressed Voltage test and Gravimetric weight loss measurement and the optimum dosage of inhibitor was determined. To obtain the optimum percentage of pond ash which gives the maximum strength, mechanical properties like compressive strength, spilt tensile strength and flexural strength were also studied. Test results indicates that replacement of sand by pond ash increases the strength of the concrete, by the addition of integral inhibitor it provides lower permeability as well as greater density which offers a better resistance to corrosion and improves durability in adverse environment.*
Index Terms— *concrete, pond ash, corrosion inhibitor, triethanolamine, durability, corrosion resistance.*

I. Introduction

Continuous research efforts have proved concrete as a versatile material. Concrete needed for a wide range of construction activity can be made easily available since all the constituents of concrete are of geological origin. Since the available sand as a fine aggregate is not able to meet the demand of construction sector, pond ash, defined as a residue and by-product of thermal power plants can be an inexpensive alternative to the river sand. The un-utilised electro static precipitator ash and bottom ash are mixed in slurry form and taken to lagoons for deposition which are known as pond ash. The compressive strength of concrete with pond ash increases with increased curing period [Arumugam K 2011]. If proper replacement level and procedure is used then pond ash concrete may be used for highway embankments, mass concreting, Plain Cement Concreting (PCC), etc. [K.M. Bagwan 2014].

The capability of concrete to resist chemical attack, weathering action and abrasion while retaining its desired engineering properties is called the durability of concrete [M.S Shetty]. Corrosion of reinforcing steel is a major problem affecting the mechanical properties of concrete. Deterioration in concrete is mainly caused by the corrosion of reinforcing steel and other embedded metals in concrete. When steel corrodes, the rust formed occupies a larger volume than the steel. This expansion produce tensile stresses inside the concrete, which leads to cracking, delamination, and spalling. Corrosion can be prevented by chemical method using certain corrosion inhibiting chemical and coating to reinforcement [Michael C. Brown 2001]. Corrosion inhibitors function by reinforcing a passive layer or by forming oxide layer and prevent outside agents and reduce the corrosion current [LouL De. Schutter 2008]. This paper presents an experimental study on the durability performance of concrete replaced with pond ash as fine aggregate and also the effect of integral type inhibitor namely triethanolamine.

II. Experimental Programme

A. Strength tests

Concrete cubes of size 150 x 150 x 150mm, beams of size 500 x 100 x 100 mm, cylinders of size 150mm diameter and 300 mm long were cast with 10%, 20%, 30%,40% and 50% of pond ash for compressive, flexural and split tensile strength tests. Triplicate specimens were cast for each percentage pond ash for 28 day strength. After 28 days curing, the specimens were tested as per IS: 516 - 1964.

B. Durability Tests

i) Rapid Chloride Permeability Test (ASTM-C1202)

Rapid chloride permeability test is used to determine the electrical Conductance of concrete which provides an indication of its resistance towards the penetration of chloride ions. The test is performed by monitoring the total amount of electrical current passed through 100mm thick and 50 mm diameter concrete discs during a period of six hours. A potential difference of 60 volt DC is retained across the ends of the concrete specimen. One lead is dipped in sodium chloride solution and the other lead in a sodium hydroxide solution. Resistance to chloride ion penetration of the specimen is obtained from the total charge passed through the cell

Fig 1: Rapid chloride permeability test

ii) Impressed Voltage Test (ASTM-C876)

Cylindrical concrete specimens of size 150 mm diameter and 300 mm length were cast with high yield strength deformed (HYSD) steel bar of 16mm diameter embedded centrally into it, in order to assess the corrosion protection efficiency under accelerated test conditions. After 28 days curing, all the specimens were taken out and dried for 24 hours then subjected to impressed voltage test. Each specimen was immersed in a tub containing 3% sodium chloride solution. The rebar projecting at the top of the specimen is connected to the positive terminals (anode) and the copper plate is connected to the negative terminal (cathode) of the DC power source applying a constant voltage of 6 volts. The applied voltage is kept constant continuously and the current response is monitored with respect to time.

Fig 2: Impressed voltage test

iii) Gravimetric Weight Loss Measurements

Steel embedded concrete cylinders were cast with various percentages of inhibitors and also without inhibitor. High yield strength deformed (HYSD) rods of size 16 mm diameter and 150 mm long were immersed in the pickling solution (Hydrochloric acid +water in equal parts) for 15 minutes to remove the initial rust. The initial weight (W1) of the rod was measured and embedded in the center of cylindrical specimens of size 75 mm diameter and 150 mm long. The specimens were subjected to 28 days curing in fresh water. After the curing period was completed the cylinders were immersed in 3% NaCl solution under alternate wetting (3days) and drying (3days) conditions over a period of 90 days. At the end of 90days the cylinders were broke open and the final weight of the specimens was taken. The difference between the initial and final weight gives the weight loss of the specimen. From the weight loss obtained corrosion rate can be calculated using the following formula:

Corrosion rate in mmpy = 87600 x W / DAT

Where W is the weight loss in milligrams, D is the density in g/cm2, A is the area in cm2, and T is the time of exposure in hours.

C. Materials Used

The materials used for the study are ordinary Portland cement of grade 53, locally available river sand used as fine aggregate, coarse aggregates of 20 mm and 12.5 mm, pond ash, con flow as superplasticizer and water of drinking quality. The properties of these materials are presented in the following sections.

i) *Cement*: The cement used in all mixtures of the study was 53 grade Ordinary Portland cement, which conforming to IS 12269:2013. Tests were conducted to determine the properties of cement.
ii) *Fine Aggregates*: River sand having density of 1.27g/cc and fineness Modulus of 3.12 was used. The specific gravity was found to be 2.52. The maximum size of fine aggregate was taken to be 4.75 mm.
iii) *Coarse Aggregates*: The coarse aggregate used in the study were 12.5 mm and 20 mm. Natural granite aggregate having density of 1.72 g/cc. the specific gravity was found to be 2.86.
iv) Pond ash: Pond ash required for the project is obtained from Nasik Thermal power station, which is one of the coal based power plants of Maharashtra.

Table 1: Chemical properties of pond ash

Sl.No	Properties	Pond ash
1	Iron Oxide	7.43
2	Aluminium Oxide	3.76
3	Silica	81.37
4	Sodium Oxide	1.42
5	Magnesium Oxide	1.44
6	Calcium Oxide	1.02
7	Loss on Ignition	1.41
8	Potassium Oxide	2.19

Table 2: Physical properties of pond ash

Sl.No	Properties	Pond ash
1	Specific gravity	2.17
2	Bulk density	741
3	Fineness modulus	1.96

v) Triethanolamine: Triethanolamine is a Colourless viscous hygroscopic liquid or crystals with slightly ammonical odour. It is a strong base with pale yellow colour. It is miscible in water.

D. Mix Proportion

Mix design of M30 grade concrete was carried out as per IS 10262-2009. Pond ash was partially replaced as fine aggregate. The final mix proportion was 1:1.24:3.07 with water-cement ratio 0.44.

E. Mix Designation

Sl.No	Mix Designation	Description
1	M0	Conventional
2	M1	M30 with 20% pond ash

3	M2	1% inhibitor in M1
4	M3	2% inhibitor in M1
5	M4	3% inhibitor in M1
6	M5	4% inhibitor in M1
7	M6	5% inhibitor in M1

III. Result And Discussions

A. Compression test

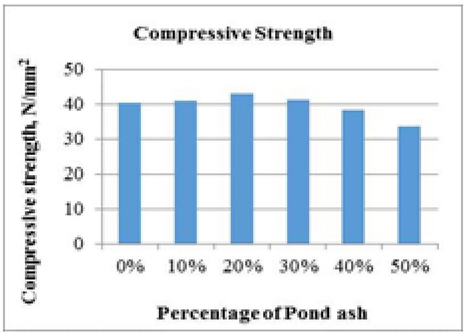

Fig 3: Compressive strength

From these values it is found that the maximum increase in compressive strength is given by 20% replacement. The strength value at 20% replacement is increased by 7.057 %.

B. Split tensile strength test

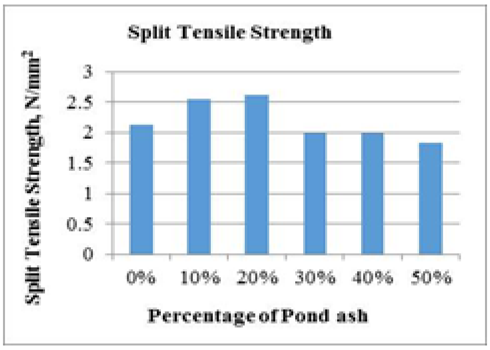

Fig 4: Split tensile strength

From these values it is found that the maximum increase in compressive strength is given by 20% replacement. The split tensile strength value at 20% replacement is increased by 18.7 % when compared to the nominal mix.

c. Flexural strength test

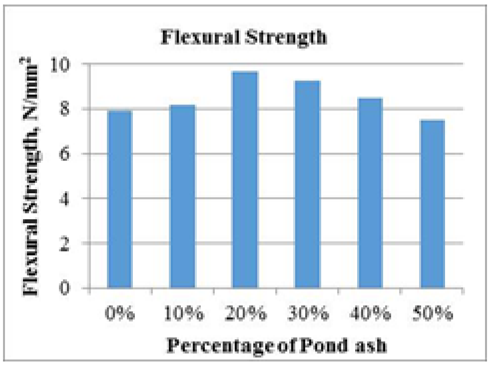

Fig 5: Flexural strength

It is observed that the maximum increase in strength is given by 20% replacement with pond ash. The flexural strength value at 20% replacement is increased by 21.84 % when compared to the nominal mix.

D.Rapid chloride permeability test

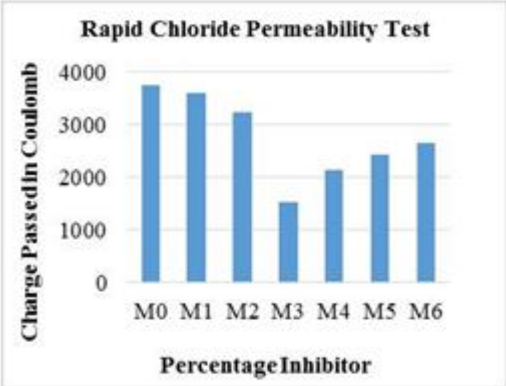

Fig 6: Rapid chloride permeability test

The RCPT value for control concrete at 28 days is found to be 3748 Coulomb. Results shows charge passed goes on decreasing with the increase in the addition of percentage of inhibitor till the addition of inhibitor percentage is 2% and charge passed increases on further addition of inhibitor. The charge passed at 2% is 1524 coulombs, which indicates a low chloride ion permeability as per ASTM C1202.

F. Gravimetric weight loss measurements

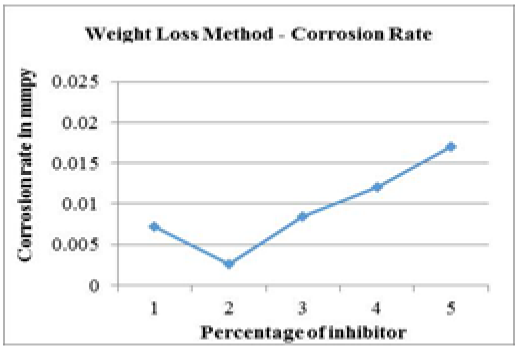

Fig 7: Corrosion rate-weight loss method

Gravimetric weight loss test results indicate the rate of corrosion decreases with the increase in the addition of inhibitor till 2% addition of inhibitor and rate of corrosion increases in the further addition of inhibitor. The rate of corrosion at 2% is obtained as 0.0026 mmpy.

E. Impressed voltage test

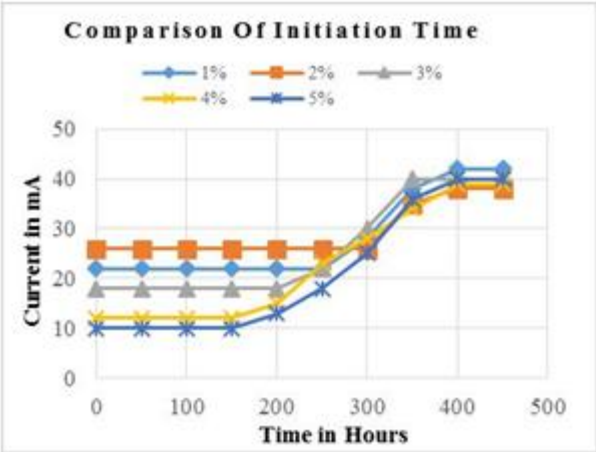

Fig 8: Corrosion initiation time

Among all the percentages added, 2% addition of triethanolamine proves to be more effective in resisting corrosion. However the corrosion resistance is slightly reduced for 3%, 4% and 5% addition of inhibitor.

IV. Conclusions

The following conclusions have been obtained from the experimental studies concerning the strength and durability behavior of inhibitor in concrete containing pond ash as fine aggregate:

- The concrete containing pond ash as fine aggregate can be successfully utilized in the construction industry with good quality materials, appropriate dosage of super plasticizer, appropriate mixing methods and proper curing thereby ensuring sustainable development against environmental pollution.
- By increasing the percentage of pond ash the workability is reduced. For obtaining the required workability the super plasticizers are added.
- The results of flexural strength, compressive strength and split tensile strength shows that 20% replacement by pond ash gives the maximum strength.
- The organic inhibitor triethanolamine protect the steel by forming a hydrophobic film on the surface of the reinforcement.
- In RCPT the charge passed through specimen with 2% inhibitor is 1524 coulombs, which indicates a low chloride ion permeability, whereas for control concrete it is found to be 3748 Coulomb.
- Gravimetric weight loss test results indicate the rate of corrosion decreases with the increase in the addition of inhibitor till 2% addition of inhibitor and rate of corrosion increases in the further addition of inhibitor. The rate of corrosion at 2% is obtained as 0.0026 mmpy.
- Specimen with 2% addition of triethanolamine proves to be more effective in resisting corrosion under accelerated test condition.
- Thus by considering durability criteria, the optimum percentage addition of inhibitor (triethanolamine) by weight of cement in concrete containing pond ash as fine aggregate is 2%.

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