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Corrosion Potential of Activated Fly Ash Concrete

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Cement concrete is the most widely used construction material in many infrastructure projects due to its versatility. The Ministry of Power, Government of India estimates generation of 600 million tons fly ash from thermal power plants by 2031-2032 which is a major concern to environment. The utilization of fly ash as construction material largely depends on its mineral structure and pozzalonic property. These two properties of fly ash can be enhanced by different methods of activation. This paper highlights chemical activation of fly ash by using CaO and Na_2SiO_3 and the corrosion potential of chemically activated fly ash concrete against corrosive environment.

Key Words: Activated fly ash, Fly ash, Calcium oxide, Sodium silicate.

INTRODUCTION

The use of mineral admixtures for cement replacement is increasing in construction industry due to the considerations of cost saving, energy saving, environmental protection and conservation of resources[1]. Mineral admixtures generally used are fly ash, rice husk ash, metakaoline, silica fume, *etc*. Addition of such materials improves various properties concrete. Fly ash is one among the commonly used mineral admixtures as it is available in large quantities in many developing countries. Similarly high volume fly ash blended cement which is now in use gives increasing strength with ageing[2]. CO_2 and other green house gas emissions are also reduced due to blending cement with these waste materials[3].

The blending materials like fly ash and rice husk ash are usually used without activation and their physico-chemical properties have been studied by many authors[4,5]. However, performance of fly ash can be improved by many means. Methods like chemical activation, mechanical activation and thermal activation are in vogue. Mechanical activation through grinding and thermal activation through heating[6] certainly improves the quality of fly ash. These methods need improved technology and machinery but at the same time, chemical properties like pH and corrosion inhibition are not improved much.

Chemical activation enhances the effectiveness of fly ash in cement concrete thereby increasing its corrosion tolerance[7]. Fly ash can be activated by chemicals like gypsum, sodium sulphate and calcium chloride[8-11].

The objective of the present investigation is to improve the quality of fly ash by chemical treatment and to study the corrosion resistance properties of improved fly ash blended Portland cement through acid resistance test, permeability test and impressed voltage study.

EXPERIMENTAL

Ordinary portland cement confirming to 43 grade IS 8112: 1989, local river sand conforming to grading zone III of IS-383-1970 and coarse aggregate hard broken granite stones passing through 20 mm sieve and retained in 10 mm sieve drawn from an approved quarry near Coimbatore, Tamilnadu, India are used for the study. Fly ash from Mettur thermal power plant, Tamilnadu, India was used in fly ash mix and further modified by chemical activation. Mix proportion used for study is given in Table-1; specific gravity of materials is given in Table-2 and properties of fly ash are given in Table-3. Acid resistance study, permeability study and impressed voltage study are used to evaluate the corrosion potential of activated fly ash concrete.

General procedure: Activation of fly ash was carried out using calcium oxide and sodium silicate of LR grade in the ratio of 1:8. The required quantity of sodium silicate in the gel form was taken in a vessel, then calcium oxide in the paste form was added and heated at a temperature of 103 ºC. Further fly ash was added and mixed thoroughly

Detection method

Acid resistance study: Concrete cubes of size 100 mm × 100 mm × 100 mm are prepared using activated fly ash and

TABLE-1
MIX PROPORTIONS

Description	Water	Cement	Fine aggregate	Coarse aggregate
Quantity	191.5 (L)	383 (Kg)	545 (Kg)	1276 (Kg)
Mix ratio	0.50	1	1.42	3.33

TABLE-2
SPECIFIC GRAVITY

Material	Specific gravity
Cement	3.15
Fly ash	2.20
Activated fly ash	2.30
Coarse aggregate	2.86
Fine aggregate	2.60

TABLE-3
FLY ASH PROPERTIES

	Min % by mass	
Chemical properties	IS:3812-1981	Fly ash MTPP
$SiO_2 + Al_2O_3 + Fe_2O_3$	70	90.5
SiO_2	35	58
CaO	5	3.6
SO_3	2.75	1.8
Na_2O	1.5	2
L.O.I	12	2
MgO	5	1.91

fly ash for various (0, 10, 20, 30, 40, 50 and 60 %) replacement ratios. After 28 days of curing in water, cube surfaces are cleaned thoroughly and weighed. Specimens are then identified with numbered plastic tokens and immersed in 3 % H_2SO_4 solution for 90 days. By using weight loss method percentage weight loss was also determined[12].

Permeability test: The water permeability test was conducted as per IS: 3085(Part 7)-1963. Concrete cubes after 28 days of curing were kept in the cube compartment of the test set up. Sides of cubes are effectively sealed using a mixture of wax and rosin to achieve water tightness. Water at a constant pressure of 0.5 MPa was maintained throughout the study period (3 days). Quantity of water percolating over the entire period of test after the steady state was noted.

The coefficient of permeability was calculated using eqn. 1

$$K = Q/AT\ (H/L) \qquad (1)$$

where, K = co-efficient of permeability in cm/sec, Q = quantity of water in milliliters percolating over the entire period of test after the steady state was reached, A = effective area of specimen in cm^2, T = time in seconds over which 'Q' is measured, H/L = ratio of pressure head to thickness of specimen, both expressed in same units.

Impressed voltage study: Fig. 1 shows the specimen for impressed voltage study. Reinforcement rods are cleaned by standard preliminary cleaning procedure and weighed. The cylindrical specimens are cast with the reinforcement at the centre. The mortar was prepared with cement and fine aggregate in the ratio 1:3. The cement content was replaced by 10-60 % of fly ash as well as activated fly ash with water binder ratio of 0.5.

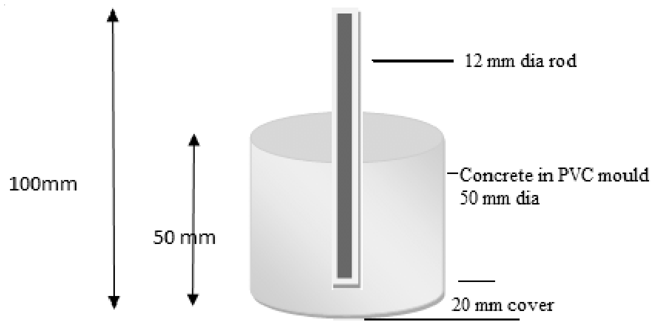

Fig. 1. Specimen for impressed voltage study

After 28 days curing, specimens subjected to 15 days wetting in 3 % NaCl solution and 15 drying process. Two such cycles are completed before initiating impressed voltage. This pre treatment of the specimens was done to accelerate corrosion. After the pretreatment specimens were subjected to impressed voltage test by impressing 12 V between rebar anode and stainless steel cathode in 5 % NaCl solution. Fig. 2 shows the schematic diagram of test set up. Time taken for an initial crack was recorded for different systems. After the specimens cracked, weight loss due to corrosion of rebar was determined[13].

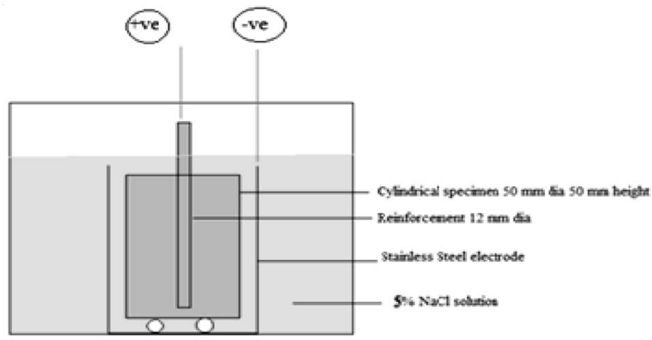

Fig. 2. Schematic diagram of impressed voltage test arrangement

RESULTS AND DISCUSSION

The properties of fly ash concrete are increased during ageing. pH value and cementing properties of fly ash blended cement is less. This is because of the glassy layer in the fly ash molecule. Ettringite (monosulphate aluminate hydrate) and C-S-H (calcium silicate hydrate) cause hardening of fly ash when mixed with water[14]. Skanly and Young[15] have reported that fly ash retards hydration of C_3A (tri calcium aluminate).

The reason for lower activity of fly ash arise from two factors mainly, the surface layer of dense glass beads and chemical stability. This dense glass layer protects the inside constituents which are porous, spongy and amorphous having higher chemical activity. The silica -alumina glassy chain of high Si, Al and low Ca is firm. This chain must be disintegrated to accelerate the pozzalonic activity. If concentration of hydroxyl ion (OH^-) is high enough, the silica-alumina glassy chain will rapidly disintegrate and produce a large number of active groups. With a small addition of CaO and Na_2SiO_3 with fly ash hydrolyzes and forms NaOH. This increases the pH of the medium thus greatly facilitating silica-alumina glassy chain corrosion. The course of NaOH effect can be concluded by the following reactions.

$$Ca(OH)_2 + Na_2SiO_3 + H_2O \longrightarrow 2NaOH + CaO{\cdot}SiO_2{\cdot}H_2O$$

(a) Neutralization of surface silanol groups.

$$-\mathrm{Si}-OH + NaOH \longrightarrow -\mathrm{Si}-ONa + H_2O$$

This neutralization repeats on new surfaces, known as corrosion of fly ash.

(b) Gradual destroying of inside silane chain, resulting in $[CSi,AlO_4]_n$

Disintegration:

$$-\mathrm{Si}-O-\mathrm{Si}- + 2NaOH \longrightarrow 2(-\mathrm{Si}-ONa) + H_2O$$

Owing to solubility of

$$-\mathrm{Si}-ONa$$

Na^+ is replaced by Ca^{2+} forming sedimentary calcium silicate hydrate. Repeating the above reaction Na_2SiO_3 can accelerate fly ash activation.

Acid resistance test: Fig. 3(a) and 3(b) shows the results for acid resistance test on fly ash and activated fly ash specimens, respectively. In the case of fly ash specimens after 3 months in acid there was reduction in weight loss (29.2 % for 10 % replacement to 14.6 % in case of 60 % replacement) as the percentage replacement increased. OPC specimens showed highest weight loss of about 30 % at 3 months exposure. In all cases of replacements by activated fly ash, weight loss was less than 18 % as against 30 % OPC specimens.

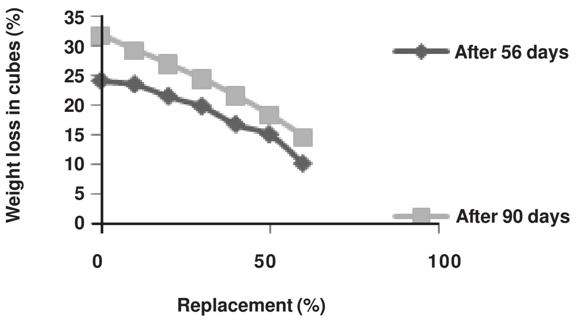

Fig. 3(a). Acid attack on fly ash cubes

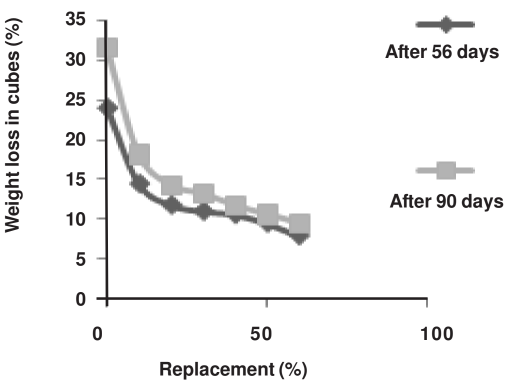

Fig. 3(b). Acid attack on activated fly ash cubes

Water permeability test: The permeability test results gives the nature of micro pores inside the concrete (Fig. 4). Least value of coefficient of permeability was obtained in the case of 40 % replacement of activated fly ash (6.01×10^{-7} cm/sec) as against (9.03×10^{-7} cm/sec) 20 % fly ash specimens.

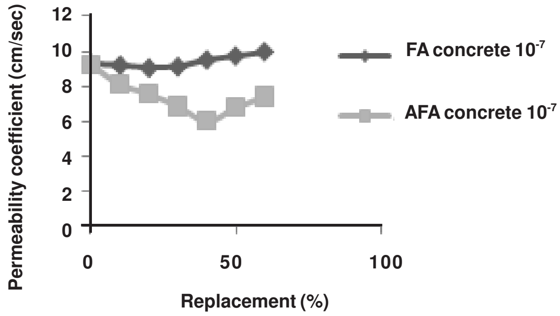

Fig. 4. Permeability test on cubes

Impressed voltage study: It is evident from the Fig. 5 that 40 % replacement in case of activated fly ash concrete got maximum time for cracking. In case of fly ash concrete, 30 % got maximum results.

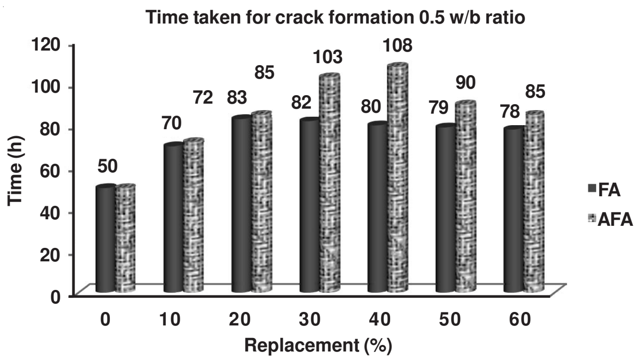

Fig. 5. Comparison of time taken for cracking of specimens

Conclusion

Corrosion of concrete structures and monuments due to polluted atmosphere and acid rain has become a topic of concern. Corrosion inhibiting concrete materials can be a solution for this issue. Fly ash concrete has a good pozzalonic property and compressive strength during ageing. The quality and efficiency of fly ash further increased by means of chemical activation[16]. Activation method employed in this study is simple and does not require additional equipments or new technology. For this purpose, CaO and Na_2SiO_3 which are easily available have been successfully used to corrode the glassy layer of fly ash and start its activation. The results show that the glassy layer destruction help the cement concrete to improve corrosion inhibition. Acid resistance test, water permeability test and impressed voltage study values indicates the effectiveness of activation as against fly ash concrete without activation and OPC[7].

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