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Strength Development of Fly Ash by Lime and Gypsum Addition for its Effective Utilization-A Laboratory Investigation

By

H.K. Naik, M.K. Mishra, V. Srikrishnan and P.K.Nayak
Mining Engineering Department, National Institute of Technology, Rourkela-769008 (Orissa)
Ph: 0661-2462603(O) FAX: 0661-2462999 ***Email: hknaik@nitrkl.ac.in***

ABSTRACT

In India approximately 70% of power generation has been through coal-fired thermal power plants. About 60% of produced coal is used for power generation. The coal which is used in power plants has an ash content of about 30-50%. Because of this high ash content, the generation of fly ash in India stands at around 118 million tons per annum. It is estimated that the fly ash generation will touch 175 million tons by 2012 occupying huge land area in addition to throwing environmental and social problems. At present the utilization of fly ashes in India is about 35 %. An effective mechanism for bulk utilization of fly ash is to fill low lying or mine void areas with strength enhancing methodology. The pH stabilization technique is a method to increase the pozzolanic property of the fly ash and hence strength of it. This paper analyses some of the physical and chemical properties of fly ashes procured from two different sources. In addition their strength enhancing characteristics have been evaluated through lime and gypsum addition. The study optimizes those Class-F fly ashes with respect to their lime content and compressive strength.

Keywords: *fly ash, lime, gypsum, compressive strength, pH*

1. INTRODUCTION

Abundant quantities of fly ash have been produced by thermal power plants situated in various parts of India. With an increasing demand for power, more and more quantities of coal are being burned to generate the thermal power leading to large quantities of coal ash. In India, fly ash produced annually by coal-burning thermal power plants amounts to more than 118 million tones [2]. This is expected to increase to 175 million tones by the year 2012 and may touch the figure 225 million tones by 2017 A.D. Environmentally safe disposal of such large quantities of coal ash is expensive. Many attempts have been made by Fly Ash Utilization Program (FAUP), Govt. of India and fly ash producers to promote the use of fly ash in various fields of engineering applications including agriculture and mining sectors. In spite of the mission mode efforts only about 35% of the total ash produced in India is gainfully utilized. One of the important ways to enhance the use of fly ash is by improving its pozzolanic reactivity. Several studies have shown that the pozzolanic properties of fly ash depend on its chemical properties like reactive silica, lime content, carbon content, and iron content, and its physical properties like fineness and specific gravity [3, 4]. While many other intrinsic properties can not be easily modified to enhance its pozzolanic property, its free lime content can easily be increased. Addition of lime enhances the pozzolanic reactivity of fly ashes containing insufficient free lime required for pozzolanic reactions with its reactive silica [1]. For fly ashes containing sufficient or excessive free lime content required for pozzolanic reactions, lime addition may not be beneficial or may even be deleterious [4, 5]. Thus even for fly ashes containing insufficient free lime content, addition of lime beyond a particular level may not be desirable. In this investigation fly ashes from two different sources have been analysed with respect to their pH characteristics.

2. BASIC CONSIDERATIONS

Typically coal ash consists primarily of silica (SiO_2), ferric oxide (Fe_2O_3), and alumina (Al_2O_3), with smaller quantities of calcium oxide (CaO), potassium oxide (K_2O), sodium oxide (Na_2O), magnesium oxide (MgO), titanium oxide (TiO_2), phosphorous pentoxide (P_2O_5), and sulphur trioxide (SO_3). In bituminous coal, three major components (SiO_2, Fe_2O_3 and Al_2O_3) accounted for about 90% of the total components, whereas lignite and sub-bituminous coal ashes had relatively high percentages of CaO, MgO, and SO_3 [6]. Fly ashes with optimum lime content produce maximum pozzolanic reactivity which in turn leads to maximum strength. Development of good strength is of great practical importance in filling low lying or mine voids.

3. METHODS & MATERIALS USED

The purpose of this paper is to optimize lime/gypsum composition that contributes to strength gain in composite specimen. This section summarizes the methods and materials used in performing the investigation such as the fly ash characterization methods and the method for preparing lime-cement- gypsum-fly ash mix specimens.

3.1 Ash Sampling

Fly ash samples from ETPS and PTPS were directly collected from Electrostatic Precipitators (ESPs) in gunny bags and transported with care to the place of experimentation. Some of the basic properties of the two fly ashes used in this investigation are listed in Table-1 as determined in the laboratory following the prescribed procedures [8, 9].

3.2 Lime and Gypsum

Commercially available chemically pure lime ($CaCO_3$) obtained from Merck Company Limited; Mumbai and analytical gypsum (Calcium Sulphate hemi hydrate) dried extra pure (Make: Merck Company) has been used in this investigation. Table-2 gives the constituents of lime used.

3.3 pH (ASTM D 4972)

The measurement of pH was carried out using Digital pH meter as per the process suggested by Jackson [7].

3.4 SEM (Scanning Electron Microscopy)

Both the fly ashes were examined using Scanning Electron Microscopy (SEM) model No. JEOL JSM-6480 LV, Japan. The purpose of this experiment is to use scanning electron microscopy (SEM) to characterize the morphology of a random group of fly ash samples from a large number of widely dispersed sources.

4. PREPARATION OF FLY ASH COMPOSITE MATERIAL

The fly ash is chosen for its low lime content as well as its availability in abundance. On the basis of the literature review, different lime proportions (0, 2, 4 and 6) % of fly ash (by weight) was selected. Similarly, percentages of gypsum were (0, 1, 2, 3, and 4 and 5) % of fly ash (by weight). The addition of lime enhances the pozzolanic reactivity of fly ash containing insufficient free lime required for pozzolanic reaction with its reactive silica. Depending on the sample dimension, designed quantities of fly ash, lime, gypsum, cement and water quantity (30 %) of the weight of fly ash sample are thoroughly mixed by hand. Then it was kept inside a polythene bag for one hour for moisture homogenization. The samples were cast to NX size core i.e. 54 mm diameter and 108 mm length for compressive strength tests. The samples were taken out of mould after 72 hours and kept in moist proof containers that were in turn placed inside humidity controlled chambers where the temperature was maintained at about 30˚C ±1%.

4.1 Compressive Strength Test

This is based on ASTM D 2166, test methods for unconfined compressive strength of cohesive soil. Compressive strength tests were performed on specimens using a strain rate equal to 1% of initial specimen length per second (equalling 0.1 mm/sec). A data acquisition system was used to record the deflection measured and load applied. The test proceeded until failure occurred. Failure was defined as the peak stress, which typically occurred at 2 to 4 percent strain**.**

5. RESULTS AND SUMMARY

5.1 Results of pH Study

Lime and gypsum were added with varying proportions. Only those results which showed higher values for pH have been reported here (Fig.1). The fly ash from PTPS exhibited highest pH 11.65 when 4% calcium & 2% gypsum were added. There is marginal improvement in pH as compared to the pH when no gypsum was added. However, the pH is increased by 79% when compared to that of raw fly ash. Similar trend was also observed for fly ash from ETPS though of less magnitude. It conforms favourably to a similar study reported elsewhere [1].

5.2 Results of SEM (Scanning Electron Microscopy) Study

In addition to the general physical characteristics and elemental composition of fly ash particles, the SEM data indicated intermixing of Fe and Al-Si mineral phases and the predominance of Ca non-silicate minerals .These results supported data obtained from pH studies. Fig.2 and Fig.3 shows the Scanning Electron Microscopy Photomicrographs of both the fly ashes at 2200 magnification.

5.3 Results of Compressive Strength Study

Fly ash from ETPS gained 70% compressive strength values when samples were cured for 14 days. Similarly fly ash from PTPS gained 67% under 14 days curing. The raw fly ashes from both the sources exhibited nil or negligible strength values. Compressive strength data for the core specimen containing fly ash obtained from PTPS fly ash and ETPS fly ash is given in Table-3. The sample mix, containing fly ash with other mixing proportions showed compressive strengths of 0.6 MPa at the 7-day age and 1 MPa at the 14-day age of curing for PTPS fly ash and 0.5 MPa at 7-day age and 0.85 MPa at 14-day age for ETPS fly ash. Fig.4 shows the compressive strength versus age relationship for PTPS and ETPS fly ash. Further investigations are going on and will be reported at appropriate time.

6. SUMMARY AND CONCLUSIONS

In general, compressive strength increased with age, and decreased with increasing fly ash inclusions in the tested range of variables. At an early 7-day age, sample specimen showed a high early compressive strength which is suitable for use in structural applications. Based upon data recorded, it can be concluded that specimen containing fly ash with appropriate proportion of certain additives can be proportioned to meet the strength and workability requirement for structural grade fly ash. The chemical, physical and mineralogical properties of fly ash had appreciable effects on performance of fly ash in filling low lying and mine void areas. Therefore, it is necessary to determine the optimum mixture proportions for each cement, lime, gypsum and fly ash source before use. It is observed that both fly ashes continue to gain substantial strength with curing.

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Table-1: Basic properties of the fly ashes used

Property	ETPS fly ash	PTPS fly ash
Sp.gr	2.20	2.35
Moisture content	0.20	0.15
pH	6.0	6.5
Specific surface area	1.24 m^2/g	0.187 m^2/g

Table-2: Chemical composition of lime used

Minimum Assay (Acidimetric)	98.5 %
Maximum limits of impurities expressed in percentages	
Substances insoluble in hydrochloric acid	0.050 %
Chloride (Cl)	0.050 %
Sulphate (SO4)	0.500 %
Heavy metals (as Pb)	0.005 %
Iron (Fe)	0.050 %

Table-3: Compressive strength of PTPS and ETPS fly ash

Particulars	Curing days	Compressive strength (MPa)	
		Fly Ash from PTPS	Fly ash from ETPS
Sample no.1	0	0.010	0.012
Sample no.2	7	0.6	0.5
Sample no.3	14	1	0.85

Fig.1: pH Variation with Various Proportions of Calcium and Gypsum

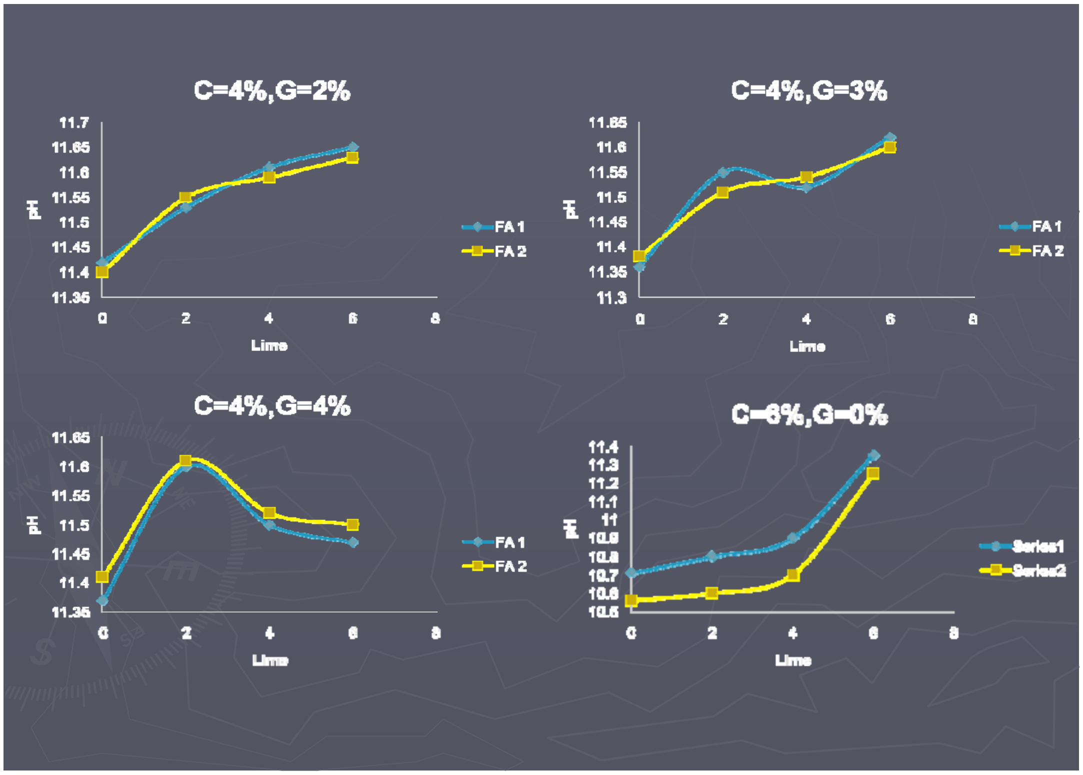
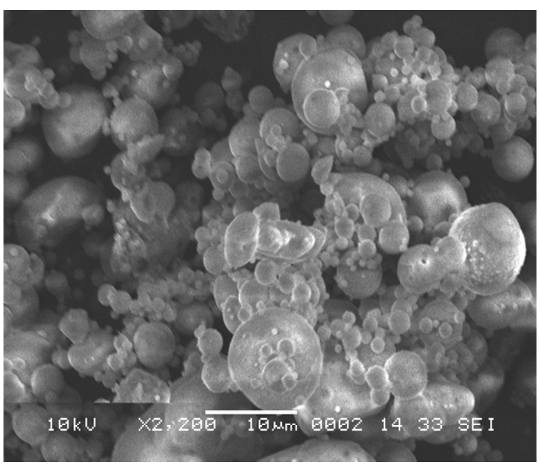


Fig.2: SEM Microphotographs of PTPS fly ash

Fig.3: SEM Microphotographs of ETPS fly ash



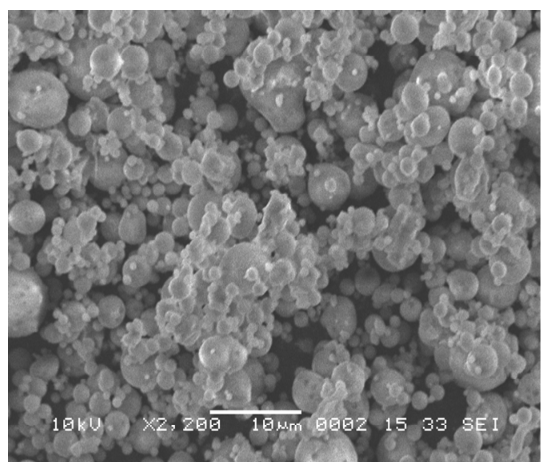


Fig.4: Compressive strength development of PTPS and ETPS fly ash in 7days and 14 days