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RESEARCH ARTICLE

EFFECT OF SODIUM SILICATE ON STRENGTHENING BEHAVIOUR OF FLY ASH COMPACTS

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ABSTRACT

This paper presents the work carried out for the improvement of mechanical properties of fly ash compacts by adding a binder. Here we added sodium silicate as a binder to the different weight fractions of fly ash, sand, gypsum and lime mixture and then compacted. These compacts were treated in normal water at different temperatures for seven days. Then compressive strength and microstructure for the different compacts were investigated. It was observed that the compressive strength of the fly ash compacts increased with addition of sodium silicate and the particles were dispersed and deviated from their globular equiaxed shape to multifaceted type in microstructure.

INTRODUCTION

Fly ash is being considered as waste material in large quantity, produced as a by-product from thermal power generation. It is creating severe environmental pollution; so much research is being conducted from more than two decades for its proper utilization in cement and brick production as well as to control environmental pollution in the surrounding areas of power plants (Koseoglu *et al*., 2010; Demirbas, 1996; Cicek andTanrıverdi, 1997; Cengizler*et al*., 2008; Kula *et al*., 2001; Uslu andArol, 2004; Shon *et al*., 2009; Cultrone andSebastián, 2009; Lingling*et al*., 2005). Using fly ash to make bricks instead of cement and clay reduces greenhouse gas and slows down global warming because large amount of carbon dioxide is produced for manufacture cement and for clay bricks production much energy burned by fossil fuel.

The fly ash particles are spherical and have the same fineness as cement so that the silica is readily available for reaction (El-Didamony *et al*., 2012). Fly ash is generally grey in color, abrasive, mostly alkaline, and refractory in nature. It contains different essential elements such as P, K, Ca, Mg and with trace amounts of Zn, Fe, Cu, Mn, B, and Mo. The pozzolanic properties and lime binding capacity of fly ash makes it useful for the production of bricks, cement and concrete (Ahmaruzzaman, 2010). Solidifying agents such as slag, calcined gypsum and dextrin are added in the production of fly ash-lime bricks (Chindaprasirt andPimraksa, 2008). Fly ash bricks are more strength and an economical alternative to conventional burnt clay bricks (Kumar, 2002). Due to its high availability and excellent property, presently in Indian scenario, fly ash is utilized in different sectors such as cement manufacture/substitution, road and embankments, low lying area filling, dyke rising, brick manufacturing, mine filling, agriculture and others (Dhadse *et al*., 2008). Fly ash bricks exhibits excellent physico-chemical and mechanical properties, including low density, micro-porosity or nano-porosity, negligible shrinkage, high strength, thermal stability, high surface hardness, fire and chemical resistance than conventional clay bricks (Pofale and Deo, 2010; Kumar, 2000; Reddy and Gourav, 2011; Dry et el., 2004; Mitra*et al*., 2010).
In the present investigation, compacts of fly ash, sand, lime and gypsum with various percentage additives of sodium silicate are prepared and treated in normal water, at room temperature, 50°C and 100°C to determine the compressive strengthand microstructure.

MATERIALS AND METHODS

The following materials are used for manufacturing the compacts.

1. **Fly ash:** Fly ash was collected from the captive power plant (CPP-II) of Rourkela steel plant (RSP). The chemical composition of the fly ash is given in Table 1.
2. **Lime:** Hydrated lime of commercial grade was used in all mixtures. Lime was brought from market and was kept in air tight polythene bags. The results of chemical composition of the lime are given in Table 2.
3. **Gypsum:** Gypsum has been obtained as phosphogypsum, a site by-product from a plant manufacturing fertilizers and chemicals. Chemical composition of the used calcinedphosphogypsum is presented in Table 3.
4. **Water:** Normal drinking water is used for compaction.

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Production of test samples

The test samples were prepared by two steps:

1. **Preparation of mixture**

   Numbers of test samples were prepared by mixing different compositions of raw materials (fly ash, lime, gypsum, sand and sodium silicate) with water. The various composition of the test mixture is given in Table 4.

2. **Compaction of mixtures**

   Ten grams of mixture was taken for each composition and compacted by die and punch to make one samples. In this way six numbers of samples were prepared for each composition. Then the samples were dried for one day.

Treatment

Then two samples of each composition kept in normal water at room temperature, at 50^{o}C and at 100^{o}C for seven days.

Characterization

Compressive tests were carried out using INSTRON 1195. Microscopic studies to examine the morphology and distribution of particles were done by a JEOL 6480 LV scanning electron microscope (SEM). The secondary electron imaging was used with suitable accelerating voltages for the best possible resolution.

RESULTS AND DISCUSSION

Influence of binder on compressive strength

The compressive strength of each sample was measured with help of Instron 1195 after the treatment. Fig 1 represented the graph of compressive strength vs percentage of sodium silicate added for samples of composition fly ash (50.69%), sand (34.56%), lime (11.52%) and gypsum (3.22%), which shown that the compressive strength increased with percentage of sodium silicate and the samples treated at room temperature exhibit high compressive strength. Similarly, Fig 2 represented the graph of compressive strength vs percentage of sodium silicate added for samples of composition fly ash (34.56%), sand (50.69%), lime (11.52%) and gypsum (3.22%), which, also shown that the compressive strength increased with increasing percentage of sodium silicate and the samples treated at room temperature exhibit high compressive strength. It is expected that by adding sodium silicate, silicon-oxygen anions found in fly ash go into solution and form polymers which begin to coagulate in the liquid during curing. The alkali of the sodium silicate then reacts with silica present in fly ash in the glass phase, strengthening this process of polymerization and coagulation, ending with the generation of a water-stable silica gel. Dehydration of the silica gel and consolidation of the structure subsequently produces an increase in the strength of the bonds, resulting in the creation of a hard, solid material (Freidinand Erell, 1995).

Table 1. Chemical composition of fly ash

Constituents	Percentage (%)
Fe_2O_3	8.1
MgO	1.14
Al_2O_3	24.98
SiO_2	55.85
P_2O_5	0.15
SO_3	1.16
K_2O	0.85
CaO	2.54
Na_2O	0.2
TiO_2	1.75
CO_2	1.56

Table 2. Chemical composition of lime

Constituent	Percentage (%)
CaO	62.55
Al_2O_3+SiO_2	25.95
MgO	3.20
Loss of Ignition	7.95

Table 3. Chemical composition of calcinedphosphogypsum

Constituent	Percentage (%)
$CaSO_4.2H_2O$	90.8
SiO_2	1.67
Fe_2O_3	0.8
MgO	0.16

Table 4. Composition of test samples

Mixture Designation	Fly ash (Wt. fraction)	Sand (Wt. fraction)	Gypsum (Wt. fraction)	Lime (Wt. fraction)	Sodium silicate (Wt. fraction)
Mix-1	50.69	34.56	3.22	11.52	0
Mix-2	47.72	32.53	3.22	11.52	5
Mix-3	44.74	30.56	3.22	11.52	10
Mix-4	34.56	50.69	3.22	11.52	0
Mix-5	33.75	49.5	3.22	11.52	2
Mix-6	32.53	47.72	3.22	11.52	5

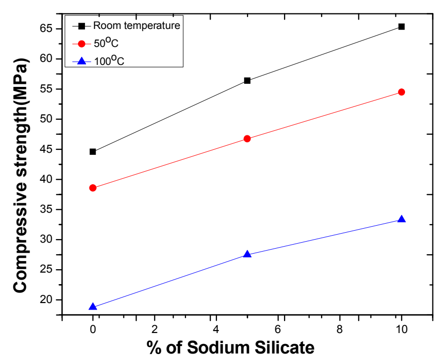

Fig. 1. Compressive strength vs percentage of sodium silicate added for samples of composition fly ash (50.69%), sand (34.56%), lime (11.52%) and gypsum (3.22%).

Surface Morphology

The microstructures of the surface of samples were observed under scanning electron microscope and were shown in following Fig 3.From the surface morphology it wasobserved that, the particles were globular, equiaxed and diffusion had taken place at inter particle boundaries in the samples without sodium silicates (for figures a, d and g). When sodium silicate was added, the particles were gradually dispersed; with nearly

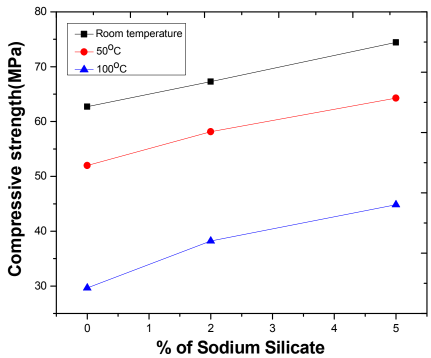

Fig. 2. Compressive strength vs percentage of sodium silicate added for samples of composition fly ash (34.56%), sand (50.69%), lime (11.52%) and gypsum (3.22%).

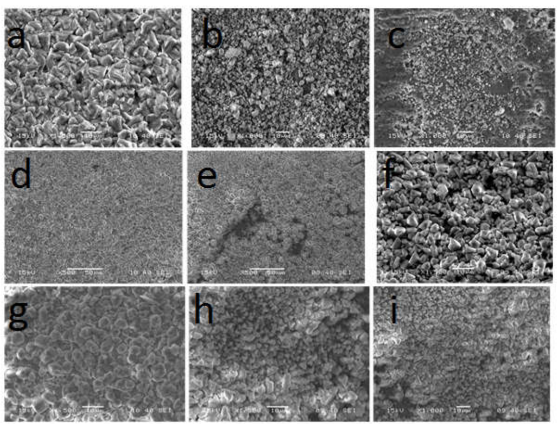

Fig. 3. SEM fractography of compacts:a) Mix-1, b) Mix-2, c) Mix-3, at room temperature, d) Mix-1, e) Mix-2, f) Mix-3, at 50°C and g) Mix-1, h) Mix-2, i) Mix-3, at 100°C.

uniform size, multiphase. Here cavities were observed in this micro structure due to water treatment. By observing all the figures we can tell that, by mixing sodium silicate the particles were deviated from their globular equiaxed shape to multifaceted type.

Conclusions

From the above investigation, it is found that the compressive strength of the fly ash compactsis increasing with addition of sodium silicate, because it produces an increase in the strength of the bonds, resulting in the creation of a hard and solid material. From the surface morphology it is clear that by addition of sodium silicate, the particles are dispersed and deviated from their globular equiaxed shape to multifaceted type.

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