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Influence of fineness of fly ash on the aggregate pelletization process

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Abstract

One of the main issues associated with fly ash is the variation in the fineness of fly ash produced within a plant and between thermal power plants, due to the variation in the quality of coal used and the production technique adopted in which pelletization of fly ash becomes complex. In this paper, the influence of fineness of fly ash is studied by collecting typical samples of fly ash from two thermal power plants. Significance of the factors influencing the pelletization of fly ash was statistically determined by adopting 2^4 with eight run and 2^5 with sixteen run fractional factorial design for fly ash with fineness of 414 m^2/kg and 257 m^2/kg, respectively. Finer fly ash exhibits higher pelletization efficiency as compared to coarser fly ash. Addition of clay binders like bentonite and kaolinite enhanced the pelletization efficiency of coarser fly ash. Amount of binder content and moisture content varies with type of binder used (with fly ash having a fineness of 257 m^2/kg), which is attributed to the difference in plasticity index. Addition of clay binder changes the relative influence of pelletization factors.

Keywords: Fly ash; Fineness; Aggregate; Pelletization; Bentonite; Kaolinite

1. Introduction

Tremendous environmental problems posed by large-scale dumping of fly ash brought the research focus towards high volume utilization of fly ash in concrete. Though effective measures have been taken in utilizing fly ash by the construction industry in various forms (such as cement replacement or addition in concrete, production of pozzolanic cement, brick and block manufacturing, embankment filling and soil stabilization), still a large amount of material remains unutilized. Increasing attention in the recent years of converting fly ash into a value added product like aggregate offers greater potential for its high volume utilization, thereby reduces use of depleting natural weight aggregates [1,2]. This artificial aggregate can be produced by adopting established techniques like pelletization or compaction. Pelletization is the process of consolidating finer moisturized particles into larger solid material without application of external force and the resultant product is light in weight due to the presence of pores. The pellets formed attains sufficient strength by the force generated by itself inside the mixer [3–5]. In the compaction technique, external force is applied, which makes the aggregates relatively denser and stronger compared to those of pelletized aggregate [6]. Amongst several types of pelletizers used in metallurgical industry, disc pelletizer is popular as it facilitates production of aggregates of various size fraction and the operation requires less space. Baykal and Doven [4] reported that the pelletization of fly ash aggregate was influenced by grain size distribution of raw material, wettability and moisture content and mechanical factors like speed and angle of disc or drum. Inter-grinding of coarser particles is reported to enhance pelletization [3]. Tay et al. [7] studied production of sintered coarse aggregates by pelletizing wastewater sludge. An earlier study by the authors concluded that (i) for a given moisture content, the use of fly ash with a fineness of 452 m^2/kg resulted in an increase in average size of

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aggregate as compared to fly ash with fineness of 340 m^2/kg [8], and (ii) coarser fly ash requires higher moisture content to produce a particular size fraction of aggregate. Further, to improve the strength and water absorption of aggregate, binders like cement, lime and bentonite were added [9].

One of the main issues associated with fly ash is the variation in the fineness of fly ash produced within the same and between thermal power plants due to the variation in the quality of coal used and the production technique adopted [2]. As the process of pelletization becomes complex with changes in fineness of fly ash, an in depth study is essential.

2. Materials and methodology

2.1. Materials

This paper focuses on the influence of fineness of fly ash using two typical samples of fly ash, one relatively coarser than the other, having chemical composition as in Table 1. Sample-1 and Sample-2 were conforming to Class C and Class F, respectively (ASTM C 618-91) [10].

As the objective of the present study is to produce coarse aggregate, the pelletization efficiency, expressed in percentage mass of aggregate of size greater than 4.75 mm produced as against the quantity of fly ash used, is used as a basis for evaluating the experimental results. A disc pelletizer with provision for adjusting and controlling the inclination of the disc (between 0° and 65° at $2\frac{1}{2}^{\circ}$ interval) and vary the speed (between 10 and 100 rpm with 1 rpm accuracy) has been used. To ensure the uniform distribution of moisture into the fly ash, a water sprayer accompanied with the air compressor has been attached to the pelletizer. Two kilogram of dry sample was observed to be optimum for effective production of aggregate.

First stage feasibility study using these two samples of fly ash indicates that (i) pelletization of fly ash with a fineness of 414 m^2/kg resulted in almost entire material being converted into aggregate and (ii) use of fly ash with a fineness of 257 m^2/kg, resulted in only 12% of the raw material forming into aggregate, and the aggregates were weak to even withstand the handling stresses. In order to enhance the pelletizability of coarser fly ash, as grinding involves considerable additional handling and energy, the option of binders has been considered in this study. As binders like cement and lime disintegrates during sintering [9], commercially available bentonite and kaolinite clay with plasticity index (difference of moisture content between liquid and plastic limits) values of 370% and 35%, respectively, were tried as binders for this coarser fly ash.

As a second stage, a study on the influence of dosage of binders on the pelletization efficiency was made by a trail and error process, wherein for each dosage of binder the water content was varied to produce maximum pelletization efficiency at a given dosage was determined. Table 2 exhibits that the type of clay binder determines its dosage required, i.e., when 4% bentonite was added to Class F fly ash, the pelletization efficiency was increased to 48%, whereas only 29% efficiency was obtained for the same percentage of kaolinite. A maximum of 98% pelletization efficiency was obtained at a dosage of 14% with bentonite. An increase in dosage of bentonite beyond this level resulted in sticking of pellets to each other leading to formation of muddy balls, which was attributed to high plasticity index of bentonite (i.e., 370%). However, for the same percentage of kaolinite content, an efficiency of 68% was observed. The maximum efficiency of pelletization achieved

Table 1
Chemical composition of fly ash

Properties	Compounds in percent by mass			
	Sample-1	Sample-2	Bentonite	Kaolinite
Type of fly ash (conforming to ASTM C618 [10])	Class-F	Class-C	–	–
Specific gravity	2.10	2.64	2.65	2.57
Fineness (m^2/kg)	257	414	–	16,000
Silicon dioxide (SiO_2) (%)	63.60	31.62	37.84	45
Calcium oxide (CaO) (%)	1.57	17.17	0.83	0.06
Alumina (Al_2O_3) (%)	28.19	30.11	17.94	38
Ferric oxide (Fe_2O_3) (%)	2.99	8.94	11.09	0.60
Magnesia (MgO) (%)	0.54	3.71	1.39	0.07
Titanium oxide (TiO_2) (%)	–	–	0.077	0.55
Sodium oxide (Na_2O) (%)	0.05	0.74	2.97	0.15
Potassium oxide (K_2O) (%)	0.003	0.10	0.09	0.10
Sulphuric anhydride (SO_3) (%)	0.26	5.72	–	–
Manganese oxide (MnO) (%)	0.03	0.02	–	–
Loss on ignition (%)	0.85	3.18	19.73	14.5

Table 2
Influence of binders on pelletization efficiency of fly ash with a fineness = 257 m^2/kg

Binder content (%)	Pelletization efficiency (%) with binder	
	Bentonite	Kaolinite
4	48	29
6	67	32
8	76	40
10	81	54
12	90	63
14	98	68
16	–	75
18	–	80
20	–	84
22	–	86
24	–	90
26	–	93
28	–	96
30	–	98