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Technical Report

Identification of design parameters influencing manufacture and properties of cold-bonded pond ash aggregate

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A B S T R A C T

This paper explores the feasibility and the process of converting of pond ashes – a waste material into artificial aggregates – a value added product. As a first step, identification of the parameters influencing manufacture and properties of artificial aggregate with pond ash has been carried out. Pond ash of both bituminous and lignite type have been chosen to make aggregate through pelletization and cold-bonding. The parameters identified are moisture content, binder dosage, pelletization enhancer and strength enhancer dosage. The range of parameters are varied and the designed experimental runs are carried out by adopting statistical technique known as central composite design of Response Surface Methodology. The physical properties of aggregate like bulk density, water absorption and open porosity and the strength property of aggregate represented through 10% fines value have been determined for the influence of parameters thus identified. Microstructure and phase composition of aggregate are represented by SEM and XRD respectively. Ordinary Portland cement, locally available hydrated lime, and hardening admixture are used as binders at varying amounts from 10% to 20% by weight. Calcium hydroxide and sodium sulphate are used as pelletization and strength enhancing admixture respectively. It is observed that the dosage of binder, strength and pelletization enhancing admixture improved the properties of aggregate. The results indicated, potentially exposes a new avenue to convert pond ash – a waste material into a value added product.

1. Introduction

A large quantity of unutilized fly ash and bottom ash are mixed with water and transported to ash ponds/dykes. Ash ponds/dykes occupy large land area causing severe contaminations to soil and water. In India alone, about 65,000 acres of valuable agricultural land is lying under the ash ponds and many million acres of such land all over the world [1]. Depending on the type of coal being used in the power plants, pond ashes are of two types, namely, bituminous pond ash and lignite pond ash.

Research attempts have been made in utilizing pond ash (i) as a replacement for cement in dry lean concrete for pavements [2], (ii) for improving the quality of cement when used as reactive raw material in black meal process of cement manufacture [3], (iii) as a foundation medium [4], (iv) as an alternative material for base and sub-base courses for pavements [5,6], (v) as a raw material for brick manufacturing [7], and (vi) as fine aggregate in concrete [8,9]. Though pond ash has been used as a construction material as mentioned above, no significant work has been done for facilitating its large-scale utilization. Hence a study on its potential for conversion into a value-added product, viz., artificial aggregate is deemed.

Pelletization, one of the widely used processes, in powder metallurgy for size enlargement, has been adapted for manufacturing aggregate. Cold-bonding, an energy-efficient and environmental friendly hardening method of manufacturing aggregates from industrial waste like fly ash, bottom ash, slag and industrial sludge, has been adapted in this study. Cold-bonding requires use of cementitious binder and/or depends on the pozzolanic reactivity of the coal ash, which finally results in a kind of matrix bonding. So far, coal ash aggregate have been produced with Class-F fly ash [10,11], Class-C fly ash [12,13], and low-calcium bottom ash [14].

Class-F fly ash and low-calcium bottom ash required the addition of cement or lime (10–30%) as binders for improving pelletization efficiency, increase in density of aggregate and development of strength [10,14]. Class-C fly ash, being pozzolanic as well as cementitious, and having higher fineness (400 kg/m^3), did not necessitate the addition of binder for pelletization [12]. This review indicated that the available literature on aggregate manufacturing dealt mostly with fly ash, bottom ash, industrial sludge, etc., and no study has been reported on use of pond ash. The present study focuses on identification of design parameters influencing manufacture and properties of cold-bonded aggregates using bituminous/lignite pond ash.

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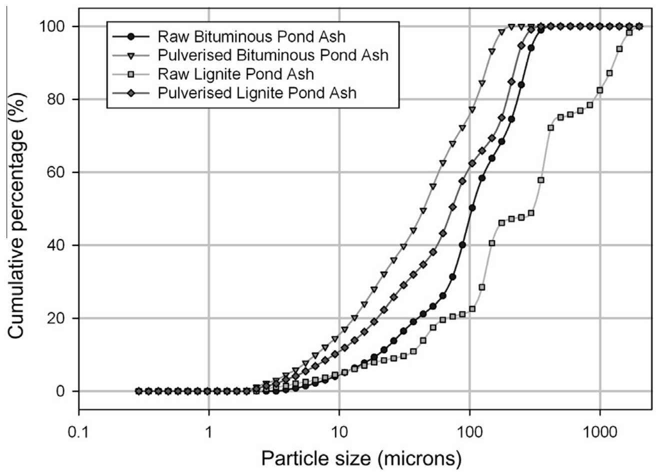

Fig. 1. Particle size distribution of pond ash.

2. Characteristics of pond ash used

Pond ash generated from the use of bituminous and lignite coal sources are collected from nearby thermal power plants. Initial attempts to pelletize the raw pond ash resulted in low pelletization efficiency (~10%) as it contained particle size greater than 0.02 mm. Hence they are sun-dried and then pulverized. The particle-size distributions for raw and pulverized pond ashes are shown in Fig. 1 which illustrates the visible increase in fineness of pulverized pond ash. The physical and chemical characteristics of pond ashes are presented in Table 1.

Significant variations in chemical composition of pond ash of two different sources are observed. Bituminous pond ash consist higher percentage of SiO_2, lower percentages in CaO and Fe_2O_3, whereas lignite pond ash contain higher percentages of CaO, Fe_2O_3 and lower percentage of SiO_2. Blaine's fineness of pulverized lignite pond ash is marginally higher than that of pulverized bituminous pond ash. Lime reactivity strength and strength activity index for both lignite and bituminous pond ash and their pozzolanic characteristics are presented in Table 2.

Pond ash of lignite source exhibited lower pozzolanic reactivity (1.67 MPa at 28 days). This is due to the fact that the source material (Class-C fly ash), being both cementitious and pozzolanic when mixed with water for pumping into ash dyke, lost its pozzolanicity, as it got hydrated. Pond ash of bituminous source exhibited relatively higher pozzolanicity (4.33 MPa at 28 days) because of its source material (Class-F fly ash) has not lost its pozzolanicity, even after pumping into ash dyke. The strength activity index of bituminous pond ash is marginally higher than that of lignite pond ash suggesting a possible influence of soluble silica facilitating continuing hydration at later ages. During wet disposal, alkalies present in coal ash react with major constituents of the ash leading to the formation of different zeolites [16]. Hence it has been decided to use binders like cement and lime in manufacturing aggregate using pond ash to improve its reactivity.

3. Manufacture of aggregate

The pelletization of pond ash has been carried out in a laboratory-scale disc pelletizer by fixing the speed and the angle that provided maximum pelletization efficiency. The pelletization efficiency is defined as the ratio of mass of aggregate of size greater than 4.75 mm produced and mass of total dry material used. For each trial, a total of 2 kg of the matrix (pond ash plus binder) is used. The pelletization process included: (i) dry mixing of the pond ash and binders for 3 min so as to ensure proper and uniform mixing of the binder in the Hobart mixer, (ii) addition of 75% of the mixing water to initiate the agglomeration process, and (iii) spraying of the remaining water to the mix during the pelletization process. The dosages of water and binder contents are represented as a percentage by weight of dry particles. The aggregate are

Table 1
Chemical and physical characteristics of pulverized pond ash.

Material	Physical properties		Chemical composition (% by mass)							
	Specific gravity	Blaine's fineness (m^2/kg)	SiO_2	CaO	Al_2O_3	Fe_2O_3	MgO	Na_2O	SO_3	LoI
Bituminous pond ash	2.17	252	57.2	2.1	25.7	6.9	1.02	0.42	2.2	14.71
Lignite pond ash	2.25	297	21.3	33.6	20.7	12	4.2	0.13	1.62	4.56

Table 2
Pozzolanic characteristics of both pulverized bituminous and lignite pond ash.

S. no.	Characteristics	Lignite pond ash		Bituminous pond ash		Pertinent code
1	Lime reactivity strength (MPa)	10 days 1.18	28 days 1.67	10 days 1.24	28 days 4.33	IS: 1727-1967, [15]
2	Strength activity index (%)	7 days 61.68	28 days 74.85	7 days 74.97	28 days 86.72	ASTM: C-311-13

Table 3
Effect of addition of calcium hydroxide on bituminous pond ash.

Binder (%)	Cement				Lime			
	Pelletization efficiency (%)		Duration (min)		Pelletization efficiency (%)		Duration (min)	
	Without $Ca(OH)_2$	With $Ca(OH)_2$	Without $Ca(OH)_2$	With $Ca(OH)_2$	Without $Ca(OH)_2$	With $Ca(OH)_2$	Without $Ca(OH)_2$	With $Ca(OH)_2$
10	32	48	16	10	30	45	14	10
15	57	73	15	9	53	71	13	8
20	78	98	13	8.5	79	96	12	7