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Effects of fly ash properties on characteristics of cold-bonded fly ash lightweight aggregates

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Abstract

The study presented herein provides a new insight into the effects of physical and chemical properties of the fly ash on the characteristics of the cold-bonded fly ash lightweight aggregates. LWAs were manufactured through the cold-bonding pelletization of two fly ashes differing in their physical and chemical properties. Moreover, one type of the LWAs was surface treated by water glass. The produced fly ash aggregates were then examined by means of ESEM micrograph, EDX spectrum, and XRD pattern to resolve the microstructural and the mineralogical characteristics of the LWAs. The findings of the study revealed that the fly ash with higher specific surface and with lower CaO content yielded higher strength LWAs. Furthermore, the surface treatment with water glass provided a marked increase in the aggregate strength and a reduction in the water absorption. The LWCs made with such LWAs had a compressive strength of as high as 60 MPa.

Keywords: Fly ash; EDX; Lightweight aggregate; Lightweight concrete; Microstructure; ESEM

1. Introduction

In the new millennium, one major challenge to the construction industry is to build structures which are environmentally sustainable. In addition to the use of pozzolans and supplementary cementitious materials, the lightweight concretes (LWCs) made with artificially manufactured lightweight aggregates (LWAs) have further made the concrete construction more sustainable and environment friendly [1,2].

Production and use of lightweight aggregate concretes have received a considerable attention for structural purposes during the last two decades. The development in the concrete technology has allowed to produce structural LWCs with a compressive strength of as high as 100 MPa [3–5]. Although, different types of LWAs for structural applications are available on the market, there is a renewed interest in the production of fly ash aggregates by cold bonding pelletization [6,7]. This process requires a medium technical skill with minimum energy consumption and follows the agglomeration of fly ash with Portland cement and/or lime at ambient temperature [7–9]. By using such aggregates, the structural lightweight concretes have been produced with a compressive strength of up to 50 MPa [10–13].

It should be noted that the properties of the LWCs greatly depend on the amount and the properties of the LWA used [14,15]. To investigate how the aggregate properties affect the mechanical properties of lightweight aggregate concrete, various studies have been carried out [16–19]. Yet, much of the investigations have concentrated on a few LWAs, available on the European market. Although, the cold-bonded fly ash aggregates have been easily used in the production of concretes, the research on the characteristics of such aggregates has not received adequate attention in the literature. Videla and Martinez [20] investigated the feasibility of producing fly ash LWAs

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through the cold bonding pelletization technique. They reported that the aggregates with Portland pozzolan cement and an outdoor hardening method appeared to be the best cost effective and technical solution allowing to obtain structural LWC. In the study of Baykal and Doven [7], the engineering performance of the moist cured fly ash pellets in combination with the effects of lime or cement additions were examined. The results obtained revealed that the lime or cement addition improved the mechanical properties of the final product, but the latter being more influential at the early age strength of the aggregates. However, the performance of the final product is not only a function of the curing procedure, amount and type of the binder used, but also the engineering properties of the material pelletized, namely, fly ash [7].

The study presented herein aims at providing some basic information on the effects of physical and chemical properties of the fly ash on the engineering performance and the microstructural characteristics of the cold-bonded fly aggregates.

2. Experimental details and methodology

2.1. Materials

Fly ashes used in the lightweight aggregate production were provided from Soma Thermal Power Plant, located in the Aegean region of Turkey. The plant burns locally produced low calory lignite coal so that approximately 30% by weight of this coal turns into ash yielding an annual fly ash production of 4 million tons. The aggregates were manufactured from two types of fly ash, as denoted A and B in Table 1, which differ in both physical and chemical properties. The fly ash A had a specific gravity of 2.56 and a specific surface area of 3206 cm^2/g while those of fly ash B were 2.31 and 3928 cm^2/g, respectively. Indeed, the major difference in the chemical composition is the amount of CaO which is 33.2% in the former and 13.6% in the latter. According to ASTM C618, CaO content in Class C fly ash is typically more than 10%, whereas it is less than 10% in Class F fly ash. Therefore, both fly ashes are classified as Class C, but fly ash A may be considered to have a more cementititous property. An ASTM Type I Portland cement was utilized as a binder in the production of both artificial aggregates and concretes. The properties of cement are also given in Table 1.

Table 1
Physical and chemical properties of fly ash A and B

Analysis report	Cement	Fly ash A	Fly ash B
SiO_2 (%)	20.09	36.94	49.10
Al_2O_3 (%)	4.1	17.2	22.98
Fe_2O_3 (%)	4.32	4.76	5.41
CaO (%)	63.42	33.22	13.61
MgO (%)	1.17	1.36	1.44
SO_3 (%)	2.35	3.82	1.54
Na_2O (%)	–	0.34	0.30
K_2O (%)	–	1.82	1.13
Cl^- (%)	0.0076	0.0045	0.0192
Insoluble residue (%)	0.36	–	–
Loss of ignition (%)	2.56	0.19	2.1
Free lime (%)	1.51	–	–
Specific weight	3.14	2.56	2.40
Specific surface area (cm^2/g)	3499	3206	3928

2.2. Lightweight fly ash aggregate production

Lightweight fly ash aggregates were produced through the cold bonding agglomeration process in a pelletizer disc. The device is original with respect to those used in the industrial plants in terms of the components and the functioning principles [7,8]. The details of the pelletization disc are sketched in Fig. 1a. The revolution speed of the disc is controlled by means of a speed controller unit and motor-reduction unit. The angle of the disc plane to the normal is adjusted via a divisor table with 1/30° sensitivity. The diameter of the pelletizer pan is 40 cm and scrapping blades were arranged such that they provided different grain size of balled material which moved in different path for ease in screening the grain size distribution (i.e., coarse size material in interior path while fine size in outer path). Moreover, an energy barrier was created which ensured more compacted fresh pellets [8]. A general view of the disc plane is shown in Fig. 1b. An optimization study was

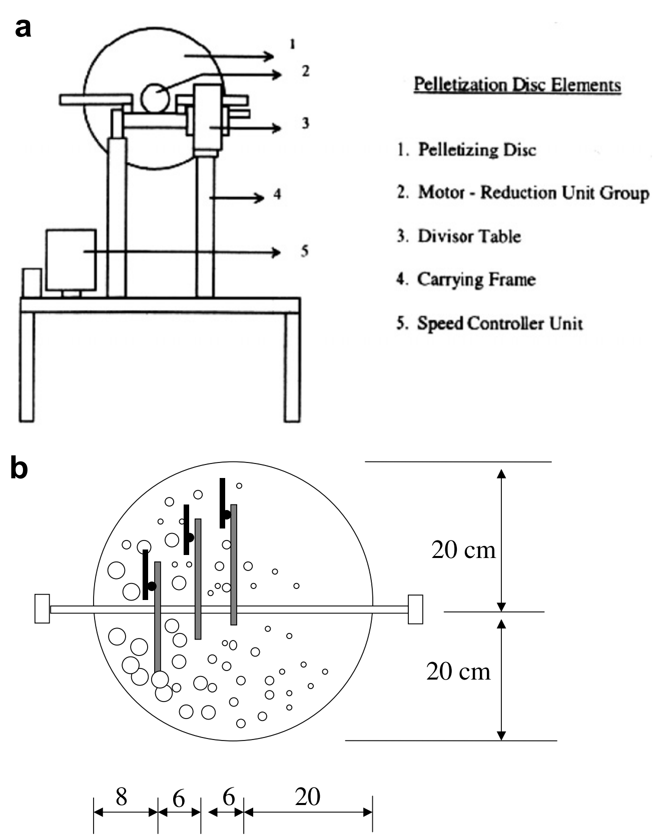

Fig. 1. (a) Pelletization disc unit (back view) and (b) scraping blades positioning (plan view).