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ScienceDirect

Procedia Engineering 148 (2016) 487 – 493

Procedia Engineering

www.elsevier.com/locate/procedia

4th International Conference on Process Engineering and Advanced Materials

Study of Fly Ash Characterization as a Cementitious Material

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Abstract

This research was conducted to compare class C and class F fly ash as cementitious materials. The fly ash was supplied by local power plants in Malaysia. The chemical composition analysis showed that class F fly ash has more Si and Al content compared to class C fly ash which affects the amount of the produced gel during the pozzolanic reactivity or/and geopolymerization. The chemical bonding analysis showed that class F fly ash has more bond structure (C–S–H, C–A–H, –Si–O–Al–, and –Si–O–Si–) than class C fly ash. Finally, the microstructure images indicated the similarity of the fly ash particles shape on both classes. Furthermore, the microstructure images showed a correlation between the chemical composition and the bond structure in terms of the high element content (Si and Al) forming the gel and the bond structure in the cementitious process during pozzolanic reaction or/and geopolymerization.

Peer-review under responsibility of the organizing committee of ICPEAM 2016

Keywords: Powder; Paste; Chemical Composition; Chemical Bonding; Microstructure

1. Introduction

Fly ash (FA) is a fine particle comes from the combustion of pulverized coal in electric power generation plants [1]. During this process, most of the volatile substances and carbon in the coal are burned off. The mineral substance associated with coal crumble and the mineral impurities (such as clay, feldspar, quartz, and shale) are carried off in

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Peer-review under responsibility of the organizing committee of ICPEAM 2016
doi:10.1016/j.proeng.2016.06.535

the form of ash by the exhaust gasses. From these processes, mainly two particle sizes are generated; the first is the coarser particles which contain heavier particles and first fall down to the furnace bottom. It is termed as the bottom ash. While the finer particles are flown together with the flue gasses and discharged to the air using a series of mechanical separators followed by highly efficient electrostatic precipitators or bag filters, so it is called as fly ash (FA) [2]. In 2013, it was recorded that Malaysia had produced more than 54 million metric tons of the FA and only 23 million metric tons (42.6% of the total FA) was used. The remaining amounts of 57.2% of the total produced FA were disposed in landfills [3]. The existence of such significant amounts forms a serious problem that has negative impacts on the society and the environment. Hence, the optimum utilization of the FA will contribute in solving this problem.

FA can be utilized in the concrete industry in two ways; the first is by using it as a partial replacement of cement based on its pozzolanic reactivity. The second is for total replacement of cement based on geopolymerization mechanism. In terms of the cementitious materials, the FA characteristics were mostly influenced by; the type and mineralogical composition of coal, the degree of coal pulverization, conditions during combustion, additives used to assist combustion or post-combustion processes, and the FA collected, handled and stored methods [4]. In general, FA consists of two categories refer to the total element of Si, Fe, and Al. Fly ash is classified as class C when the total content of these elements is more than 50%, and class F when it is more than 70%. Furthermore, FA is categorized into low calcium content (low Ca) and high calcium content (high Ca). For the low Ca type the Ca content should be in the range of 8-20% and for the high Ca the Ca content should be more than 20%. FA particles are spherical in shape and mostly glassy (amorphous) in nature with particles sizes less than 50 μm [4].

Referring to these characteristics, FA is known as a pozzolan material and in some cases as a self-cementitious material. In terms of pozzolan materials; FA is used as a partial cement replacement where the $Ca(OH)_2$ reacts with aluminate-silicate phase to produce calcium-silicate-aluminate hydrates [5,6]. This happens during the cement hydration associated with the presence of SiO_2 and Al_2O_3 in the amorphous form. On the other hand, FA is also used as a self-cementitious material in geopolymer cement where the FA is able to totally replace the cement. In this condition, the presence of aluminosilicate phases (from SiO_2 and Al_2O_3) produce the structural bond (-Si-O-Al-O-Si) based on the geopolymerization mechanism [5, 6]. Further studies are necessary in terms of FA characterization as a cementitious material considering the sustainability of this material and the ability to reduce its negative impact on society and environment, especially in Malaysia.

2. Material and experimental works

Two different types of FA powder were used in this research. The first was class C fly ash supplied by the electric generation plant in Manjung, Perak. The second was class F which came from the electric generating plant in Paka, Terengganu. It was classified according to the ASTM 618 standards requirement for the coal FA in terms of its chemical composition, particle size, and particle shape. The X-ray fluorescence (XRF) was used to find the chemical composition of the powder [7, 8], fourier transform infrared spectrometer (FTIR) was used for powder identification analysis [9, 10], and scanning electron microscope (SEM) was used to find the particle shape and the chemical reactivity of cementitious process [11, 12].

The paste was made according to the ASTM C305 standard procedures for mechanical mixing of cement paste and mortar [13]. Dry paddle and bowl were placed in the mixer and the mixing water (pozzolanic paste) or alkaline solution (geopolymer paste) was poured into the bowl. Binder powder was added into the bowl and kept for 30 seconds. Then, they were mixed at slow speed for 30 seconds after which it was stopped for 15 seconds. During the stop, the pastes were scraped from the side of the bowl and continued to mix on medium speed for 60 seconds. The fresh mix was poured into 50x50x50 mm steel cubic molds and each layer was tapped 16 times in two different directions to ascertain the removal of any air bubbles. The samples were taken from the mold after 24 hours and cured in water at temperature of 20 ± 2 °C for pozzolanic paste or cured at ambient temperature for geopolymer paste for 28 days.