Construction and Building Materials 25 (2011) 4095–4104

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Review

Effect of palm oil fuel ash fineness on the microstructure of blended cement paste

Wunchock Kroehong [a], Theerawat Sinsiri [a,*], Chai Jaturapitakkul [b], Prinya Chindaprasirt [c]

[a] School of Civil Engineering, Institute of Engineering, Suranaree University of Technology, Nakorn Ratchasima 30000, Thailand
[b] Department of Civil Engineering, Faculty of Engineering, King Mongkut's University of Technology Thonburi, Bangkok 10140, Thailand
[c] Sustainable Infrastructure Research and Development Center, Department of Civil Engineering, Faculty of Engineering, Khon Kaen University, Khon Kaen 40002, Thailand

ARTICLE INFO

Article history:
Received 12 January 2011
Received in revised form 2 March 2011
Accepted 22 April 2011
Available online 25 May 2011

Keywords:
Palm oil fuel ash
Amorphous
Compressive strength
Thermogravimetric
Porosity

ABSTRACT

This paper presents the effect of palm oil fuel ash fineness on the microstructure of blended cement paste. Palm oil fuel ash (POFA) was ground to two different finenesses. Coarse and high fineness palm oil fuel ash, with median particle sizes of 15.6 and 2.1 μm, respectively, were used to replace ordinary Portland cement (OPC) at 0%, 20% and 40% by binder weight. A water to binder (*W*/*B*) ratio of 0.35 was used for all blended cement pastes. The amorphous ground palm oil fuel ash was characterized by the Rietveld method. The compressive strength, thermogravimetric analysis and pore size distribution of the blended cement pastes were investigated. The test results indicate that the ground palm oil fuel ash was an amorphous silica material. The compressive strengths of the blended cement pastes containing coarse POFA were as high as that of OPC cement paste. Blended cement paste with high fineness POFA had a higher compressive strength than that with coarse POFA. The blended cement pastes containing 20% of POFA with high fineness had the lowest total porosity. The $Ca(OH)_2$ contents of blended cement paste containing POFA decreased with increasing replacement of POFA and were lower than those of the OPC cement paste. In addition, the POFA fineness had an effect on the reduction rate of $Ca(OH)_2$. Furthermore, the critical pore size and average pore size of blended cement paste containing POFA were lower than those of the OPC cement paste. The incorporation of high fineness POFA decreased the critical pore size and the average pore size of blended cement paste as compared to that with coarse POFA.

© 2011 Elsevier Ltd. All rights reserved.

Contents

* Corresponding author. Tel.: +66 4422 4420; fax: +66 4422 4607.
E-mail address: sinsiri@g.sut.ac.th (T. Sinsiri).

0950-0618/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.conbuildmat.2011.04.062

1. Introduction

The Portland cement clinker process results in the emission of CO_2. Every ton of Portland cement produces around 850 kg of CO_2 emitted to the atmosphere, thus causing greenhouse effects [1]. Therefore, it is necessary to reduce the production of Portland cement clinker. To solve this problem, the partial replacement of ordinary Portland cement with pozzolanic materials has been proposed. Pozzolanic materials, such as fly ash, rice husk ash, palm oil fuel ash and baggage ash, are used as mineral admixtures to reduce the cement content in the mixtures. These materials have been reported to increase the durability of paste, mortar and concrete [2–4].

Palm oil fuel ash (POFA) is a by-product from biomass thermal power plants where oil palm residues are burned to generate electricity. More than approximately 100,000 tons of palm oil fuel ash are produced every year in Thailand [5]. Palm oil fuel ash is rarely utilized, and it may add to future environmental problems. Many researchers have studied the use of POFA as a partial replacement of cement in concrete. The main chemical constituent of palm oil fuel ash is silicon dioxide [4,6]. Tangchirapat et al. [4] found that ground palm oil fuel ash is a good pozzolanic material and can be used to replace Portland cement up to 30% by binder weight. Sata et al. [7] also showed that POFA with high fineness has an excellent pozzolanic reaction and can be used as a supplementary material to produce high strength concrete. In addition, the utilization of POFA can improve concrete strength and water permeability [5]. Furthermore, the partial replacement of OPC with POFA assists in the sulfate resistance [8] and chloride resistance of concrete [2].

Silicon dioxide (SiO_2) and aluminum trioxide (Al_2O_3) contents in pozzolanic material react with calcium hydroxide ($Ca(OH)_2$) to produce CSH, C_2ASH_8 and C_4AH_{13}. Most researchers have studied $Ca(OH)_2$ in cement paste containing pozzolanic material by thermogravimetry (TG). The $Ca(OH)_2$ content is reduced with increasing replacement of pozzolanic material and fineness [9]. Barbhuiya et al. [10] found that the reduction of the $Ca(OH)_2$ content indicates consumption in the pozzolanic reaction. In addition, the use of pozzolanic material to partially replace cement reduces the $Ca(OH)_2$ content in concrete, which could improve the sulfate resistance of the concrete. Furthermore, Chaipanich and Nochiya [11] used differential thermal analysis (DTG) to determine the hydration products involved and explained the increase in the compressive strength of paste. They showed that blended cement paste containing fly ash and silica fume reduces the amount of $Ca(OH)_2$ content while the mass loss of ettringite, C–S–H and C_2ASH_8 increases when the curing time is increased.

The porosity and pore structure are very important for permeability and durability. The pore system in cement-based materials consists of two types of pores [9,12]: (a) gel pores with a diameter less than 10 nm that affect shrinkage and fatigue and (b) capillary pores that are divided into large capillary pores with diameters between 50 and 10,000 nm, which affect the compressive strength and permeability, and medium capillary pores with diameters between 10 and 50 nm, which influence the compressive strength, permeability and shrinkage. Khatib and Wild [13] studied cement pastes containing metakaolin at 5%, 10% and 15% and found that the pore size of a cement paste depends on refinement of the pore structure. In addition, Chindraprasirt et al. [14] used fly ash to replace Portland cement and showed that the cement paste containing fly ash had a smaller average pore diameter than that of control cement paste. In addition, Halamickova et al. [15] studied water permeability and chloride ion diffusion in Portland cement mortar and showed that they are influenced by the critical pore size.

Many researchers have already reported on the influence of palm oil fuel on the physical properties of mortar and concrete, including compressive strength, sulfate resistance and chloride resistance. However, the pore size distribution and microstructure of blended cement pastes containing palm oil fuel ash with different finenesses have not been well established. An understanding of the influence of the fineness of palm oil fuel ash on the pore size distribution and microstructure of cement paste could lead to an increase in the use of palm oil fuel ash in concrete and could be productive for the environment by reducing the volume of waste disposed of in landfills. Thus, the objective of this research was to study the effect of palm oil fuel ash fineness on the microstructure of blended cement paste. The chemical properties and amorphous structure of ground palm oil fuel ash were determined. The effects of ground palm oil fuel ash with two different finenesses on the compressive strength, calcium hydroxide and pore size distribution of blended cement pastes were investigated.

2. Experimental details

2.1. Materials

Type I Portland cement was used in this study. Palm oil fuel ash (POFA) from a thermal power plant in Thailand was used as a pozzolan. The POFA was sieved through a No. 16 sieve to remove large particles and incompletely combusted materials [16,17]. The POFA was ground to two different sizes. The first fineness was ground to have the same as that of OPC with grinding machine. The second fineness was ground by attrition mill for 60 min at 1000 rpm using 2 mm diameter steel ball [18,19]. The abbreviations G1 and G2 were used to identify the ground POFA as having the same particle size cement and the smaller particle size, respectively.

SEM photos of POFA with different finenesses are shown in Fig. 1. G1POFA and G2POFA consist of irregular and crushed shaped particles. A similar observation has also been reported by other researchers [4]. The physical properties of OPC and POFA are given in Table 1. The specific gravity of OPC was 3.14, and those of G1POFA and G2POFA were 2.36 and 2.48, respectively. The Blaine fineness values of OPC, G1POFA and G2POFA were 3600, 6700 and 14,900 cm^2/g, respectively. The specific gravity and specific surface area of POFA increased with increasing grinding time [8,20,21]. The median particle sizes of OPC, G1POFA and G2POFA were 14.6, 15.6 and 2.2 μm, respectively. Fig. 2 shows a comparison of the particle size distributions of type I Portland cement and POFA. The two group of POFA particle size are similar to the particle size of the cement and smaller, respectively.

2.2. Mix proportion and curing

Type I Portland cement was partially replaced by POFA (G1POFA or G2POFA) at the rate of 0%, 20%, and 40% by binder weight. The water to binder (W/B) ratio was constant at 0.35 for all mixtures. The cast specimens were covered with plastic to prevent water loss. After casting for 24 h, the specimens were removed from the mold. Thereafter, they were cured in saturated lime water at a temperature of 23 ± 2 °C. The mix proportions of cement paste and blended pastes containing POFA are given in Table 2.

2.3. Compressive strength

Cube specimens of 50 × 50 × 50 mm were used for compressive strength tests of the pastes. The strengths were determined at 7, 28, 60 and 90 days according to ASTM C 109 [22]. The compressive strength of the pastes at each age was the average value of five samples.

Download English Version:

https://daneshyari.com/en/article/259443

Download Persian Version:

https://daneshyari.com/article/259443

Daneshyari.com