Construction and Building Materials 165 (2018) 72–81

Contents lists available at ScienceDirect

Construction and Building Materials

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

Changes in color and thermal properties of fly ash cement mortar after heat treatment

Yuliang Zhang [a,b], Qiang Sun [a,b,*], Xiuyuan Yang [c]

[a] Key Laboratory of Coalbed Methane Resources and Reservoir Formation Process of the Ministry of Education, China University of Mining and Technology, Xuzhou, Jiangsu Province 221116, China
[b] School of Resources and Geosciences, China University of Mining and Technology, Xuzhou, Jiangsu Province 221116, China
[c] Hydrogeological and Environmental Geological Survey Center of China Geological Survey, Baoding, Hebei Province 071051, China

HIGHLIGHTS

- We conduct an experimental research of fly as cement mortar at 3 fly ash replacement ratios.
- Color change reveals a critical temperature interval.
- Thermal conductivity was obtained of poet-heated fly ash cement mortar up to 800 °C.
- FA replacement ratio has a considerable influence on mass loss, density ratio and thermal conductivity.

ARTICLE INFO

Article history:
Received 11 September 2017
Received in revised form 6 November 2017
Accepted 4 January 2018

Keywords:
Fly ash cement mortar
High-temperature
Color
Thermal conductivity

ABSTRACT

Fly ash (FA) is a powdery substance discharged by power plants after burning coal or other fossil raw materials. The storage and reuse of FA have been under debate since the release of FA into the atmosphere could be detrimental to human health. Fortunately, FA has been mostly collected by plants, and these large amounts of collected FA have led to its reuse, which not only reduces pollution, but FA can be also used in lieu of other materials, such as cement, for environmentally friendly building materials. However, the properties of building materials will undergo deterioration at high temperatures. Therefore, in this study, the influence of heat treatment at high temperatures on FA cement mortar is examined in relation to the color and thermal conductivity changes. Color changes are an apparent indicator, for example, of the variation in moisture content. Thermal conductivity (λ) is an important parameter for evaluating the heat transport properties of materials. Mass loss and density also affect thermal conductivity. In this study, 15 FA cement mortar samples are made from mixtures that contain 3 different FA replacement percentages: 10%, 20% and 40%, for a total of 45 samples. The samples undergo heat treatment at temperatures that range from room temperature to 800 °C before testing is carried out. A color meter and a thermal conductivity tester are used to obtain the color parameters L*, a*, b* and thermal conductivity, respectively. The samples are also sprayed with a phenolphthalein reagent after treatment to qualitatively observe the changes in pH. It is found that a temperature range of 400–600 °C is critical in which the pH of the mortar decreases due to carbonization and the decomposition of calcium hydroxide, which lead reduced lifespan of the FA cement mortar. The thermal conductivity also decreases at higher temperatures, and is linearly correlated with the density ratio. The experimental results show that the FA percentage has a considerable influence and therefore, there could be an optimum FA percentage.

1. Introduction

Due to rapid economic development and urban population growth worldwide, there have been an increasing number of new building constructions, especially in China. FA is one of the materials used in building materials [1]. However, the storage and reuse of FA have become a hotly debated topic of many researchers in recent years [2,3].

FA is a powdery substance discharged by power plants after burning coal or other fossil raw materials [4–6]. If FA is released into the atmosphere due to improper handling procedures, it is harmful to humans and may result in aggravation of asthma,

* Corresponding author at: Key Laboratory of Coalbed Methane Resources and Reservoir Formation Process of the Ministry of Education, China University of Mining and Technology, Xuzhou, Jiangsu Province 221116, China.
E-mail address: sunqiang04@cumt.edu.cn (Q. Sun).

https://doi.org/10.1016/j.conbuildmat.2018.01.029
0950-0618/© 2018 Published by Elsevier Ltd.

Table 1
Composition of OPC and FA.

Chemical composition (%)	OPC	FA
Sodium oxide (Na_2O)	0.17	0.50
Magnesium oxide (MgO)	2.50	0.76
Aluminum oxide (Al_2O_3)	7.00	32.90
Silicon dioxide (SiO_2)	22.50	54.40
Potassium oxide (K_2O)	0.78	1.40
Calcium oxide (CaO)	59.00	2.70
Ferric oxide (Fe_2O_3)	3.31	4.10
Manganese oxide (MnO)	0.03	0.03
Titanium dioxide (TiO_2)	0.30	1.30
Phosphorus pentoxide (P_2O_5)	0.10	0.14
Sulfur trioxide (SO_3)	1.80	0.40
Physical properties		
Specific gravity	3.15	2.30
Specific surface (m^2/kg)	310	410
Compressive strength 3 days (MPa)	25.2	
7 days (MPa)	33.1	
28 days (MPa)	46.3	
Initial setting time (min)	166	
Final setting time (min)	242	

Table 2
Mix proportion of mixtures.

Type	Mix proportion (kg)				No. of samples	Replacement percentage
	FA	OPC	Sand	Water		
1	0.44	3.96	13.20	2.25	15	10%
2	0.80	3.20	12.00	2.10	15	20%
3	1.60	2.40	12.00	2.15	15	40%

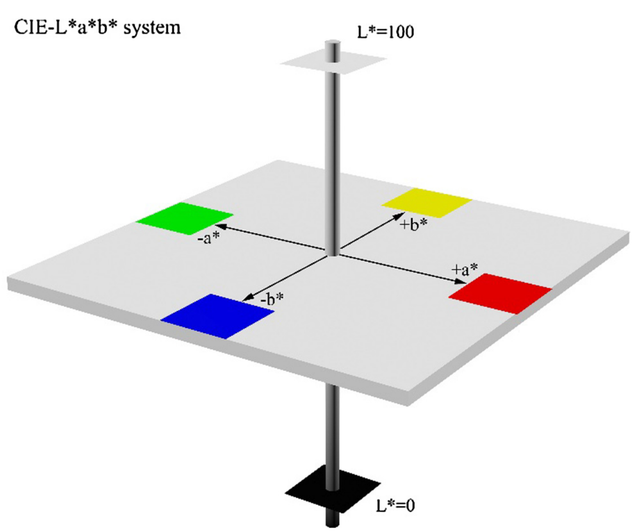

Fig. 1. CIE-L*a*b* system.

nonfatal heart attacks, or even lung cancer [7]. Fortunately, most of the FA has been collected by plants owing to the increasing awareness of environmental protection and various environmental laws, but large amounts of FA collected cause another problem – its storage or reuse.

Compared to the storage of FA, its reuse has many advantages. The greatest advantage is that its reuse not only reduces pollution, but can be also used in lieu of other polymerized materials. In recent years, the use of FA as a replacement material for cement has become more prevalent for realizing environmentally friendly building materials, such as concrete and mortar, which have a wide range of applications [8,9].

Most of the works in the literatures on FA concrete or mortar focus on its strength. Variations in the compressive strength with curing time have been examined by many researchers [10–22]. Meanwhile, the influence of other variables on compressive strength has also been studied, such as the FA replacement percentage [3,23–26], curing regime [27] and hardened density [28].

The properties of FA concrete or mortar have also been studied. In the curing process of concrete, the temperature will increase due to the hydration of Portland cement paste [29]. When the temperature is subsequently decreased, cracks are produced. However, increasing the FA replacement percentage can inhibit temperature increases in concrete [30]. Therefore, there is less damage incurred from cracks in FA cement concrete as opposed to ordinary Portland cement (OPC) concrete [31]. FA cement concrete or mortar also has a lower thermal diffusion than OPC concrete or mortar [10,32]. Other influences of FA on concrete or mortar have also been studied, such as electrical conductivity [33], thermal conductivity [34–36], pH with time [37], preliminary electrochemical cementation [38] and pore characteristics [39].

Under high temperatures after heating, the properties of building materials will undergo deterioration, which requires further study. Some researchers have shown that the compressive strength of FA cement concrete will decrease at higher temperatures [40–42]. Increasing the temperature or FA replacement percentage can accelerate the carbonization process [43].

These previous research works have provided the fundamental basis of building materials, which include FA cement mortar, but other properties after heating also need to be further examined, such as color and thermal conductivity.

Color changes are a visible and an apparent indicator, through which other properties can be quickly and indirectly assessed. For example, color changes can show the variation in moisture content. By spraying a phenolphthalein reagent onto the surface of a material, the alkalinity can be preliminarily determined, which has a considerable influence on corrosion resistance.

Thermal conductivity is a thermal property and an important parameter of interest for evaluating the heat transport properties

Fig. 2. DRE-2C thermal conductivity tester and probe placement.