Construction and Building Materials 104 (2016) 134–141

Contents lists available at ScienceDirect

Construction and Building Materials

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

Particle characteristics and hydration activity of ground granulated blast furnace slag powder containing industrial crude glycerol-based grinding aids

Jihui Zhao [a,b,*], Dongmin Wang [b], Peiyu Yan [a], Shijiao Zhao [b], Dawang Zhang [b]

[a] Department of Civil Engineering, Tsinghua University, Beijing 100084, China
[b] China University of Mining & Technology, Beijing 100083, China

HIGHLIGHTS

- C-GLY can effectively optimize the particle characteristics of ground GBFS powder.
- Hydration degree and activity index of ground GBFS are also improved by C-GLY.
- The properties of C-GLY are close to that of TEA and better than that of glycerol.
- C-GLY as GBFS grinding aids is very feasible.

ARTICLE INFO

Article history:
Received 14 July 2015
Received in revised form 27 October 2015
Accepted 6 December 2015
Available online 14 December 2015

Keywords:
Granulated blast furnace slag
Crude glycerol
Grinding aids
Particle characteristics
Hydration activity

ABSTRACT

This paper investigates the viability of industrial crude glycerol (C-GLY) as grinding aids of the granulated blast furnace slag (GBFS). The effects of C-GLY on the particle characteristics and hydration activity of GBFS are studied. The results show that C-GLY can effectively optimize the particle characteristics of ground GBFS. Both the sieve residue and angle of repose of GBFS powder with 0.08 wt% C-GLY are obviously reduced and the specific surface area is improved. The particle size distribution of GBFS powder with C-GLY becomes narrow and particle content of less than 32 μm is obviously increased. In the initial grinding period, the uniformity coefficient of GBFS powder is reduced by C-GLY, while the uniformity coefficient is increased in the latter grinding period. Additionally, 7d and 28d hydration degree of ground GBFS (50 min grinding time) paste with C-GLY are improved by 4.9% and 5.8%, respectively. For the different grinding time, all the activity indexes of different ground GBFS powder are effectively improved by C-GLY. And the uniformity and compactness of hydration products of blended cement paste containing ground GBFS with C-GLY are also improved. By contrast, the action effects of C-GLY on the grinding performance and hydration activity of GBFS are close to that of TEA and better than that of glycerol. Due to the huge cost advantage of C-GLY, its comprehensive performance is better than that of other grinding aids, selecting C-GLY as GBFS grinding aids is feasible.

1. Introduction

Granulated blast furnace slag (abbreviated GBFS) is an industrial solid waste generated in the steelmaking process [1,2]. It is rich in CaO, SiO_2, Al_2O_3 in chemical compositions and the mineral phases of GBFS are mainly composed of glass phases [3,4]. Based on its chemical and mineral compositions, GBFS has a good hydration activity [5–8]. Currently, GBFS has been widely used as supplementary cementitious materials of cement and concrete [6,9–13]. The smaller the particle size of GBFS is, the better the hydration property of GBFS is [5,14,15]. However, the grindability of GBFS is poor [16,17]. What's more, in the grinding process of GBFS, it is also accompanied by some phenomena such as fine particles agglomeration and re-healing of particle fracture surface, resulting in GBFS being difficult to be ground, so that the grinding efficiency of GBFS is low and the energy consumption is great [18–21].

In recent years, some of polar organic chemicals as grinding aids are extensively studied to improve the grinding efficiency and hydration performance of cement, slag, fly ash and so on

* Corresponding author at: Department of Civil Engineering, Tsinghua University, Beijing 100084, China.
E-mail address: zhaojihui324@163.com (J. Zhao).

http://dx.doi.org/10.1016/j.conbuildmat.2015.12.043
0950-0618/

[22–25]. The reason is that these organic grinding aids have strong adsorption property on the solid particles and the grinding aids molecules adsorbed on the particles can change the physical and chemical properties of particles surface in the grinding process [26–29]. Currently, the most common grinding aids mainly include triethanolamine, triisopropanolamine and polybasic alcohol (such as glycerol, ethylene glycol and propylene glycol) in China [23,25,30]. However, these organic chemicals are very expensive, for example, the price of triethanolamine or triisopropanolamine is 10,000–15,000 RMB per ton and the polybasic alcohol also are 5000–10,000 RMB per ton in China, which limits application of these organic chemicals in the grinding of GBFS [18]. Selecting cheap and efficient grinding aids becomes urgent and significant for many GBFS powder manufacturers.

The industrial crude glycerol (abbreviated C-GLY) is an industrial by-product of the biodiesel, oleochemicals and soap production, the amount of which produced annually is large [31,32]. It is sometimes regarded as a waste product because of the cost associated with its disposal. Although there have been a number of reports on the conversion of industrial crude glycerol to value-added products through chemical methods, its utilization remains limited [33,34]. The main compositions of C-GLY include free glycerol and methanol (the two accounted for 60–90%), monoglyceride, diglycerides, alkali, lipa and other organic volatile residue [35], which belongs to polar organic substances and actually can be seen as a glycerol-based composite grinding aid. As the annual production of C-GLY is large, its price is very cheap (about 1000 RMB per ton in China), only one tenth of triethanolamine or triisopropanolamine and one fifth of polybasic alcohol. Therefore, C-GLY as GBFS grinding aids has a great potential and application value.

The purpose of this paper is to investigate the possibility of C-GLY as grinding aids of GBFS. The particle characteristics of GBFS containing C-GLY are studied from the sieve residue, specific surface area, angle of repose and particle size distribution, and the hydration activity of ground GBFS powder is studied from the hydration degree and activity index.

2. Experimental

2.1. Raw materials

(1) The GBFS used was supplied from Xuanhua steel plant in Hebei province of China, and the cement used was portland cement with the strength grade of 52.5 from Beijing Cement Plant of China. Both the chemical compositions of GBFS and cement were listed in Table 1.
(2) C-GLY used (as shown in Fig. 1) was supplied from a chemical Co., Ltd in Jiangsu province of China. Its purity and pH value were 83 wt% and 4.8, respectively. The IR spectrum of C-GLY is shown in Fig. 2. As seen from Fig. 2, there are a large number of hydroxyl functional groups (at 3200–3650 cm^{-1} adsorption peak in IR spectrum) in the molecular structure of C-GLY. Compared with glycerol, C-GLY molecular also has a small amount of ester functional groups (at about 1750 cm^{-1} adsorption peak in IR spectrum). Both the triethanolamine (abbreviated TEA) and glycerol (GLY) used was the chemically pure reagents, produced by Beijing Chemical Reagent Factory of China, and then were diluted with water to the concentration of 83 wt%.
(3) The sand used in the mortar mixtures was the China ISO standard sand and produced according to the ISO 696 and EN196-1 standard by Xiamen ISO Standard Sand Co., Ltd. Both CaO and NaOH reagents used were chemically pure, produced by Beijing Chemical Reagent Factory of China.

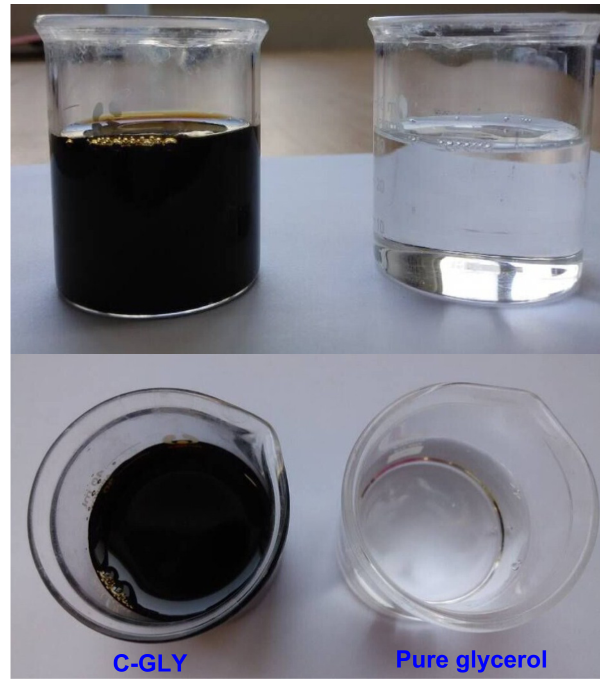

Fig. 1. Appearance of C-GLY and pure glycerol.

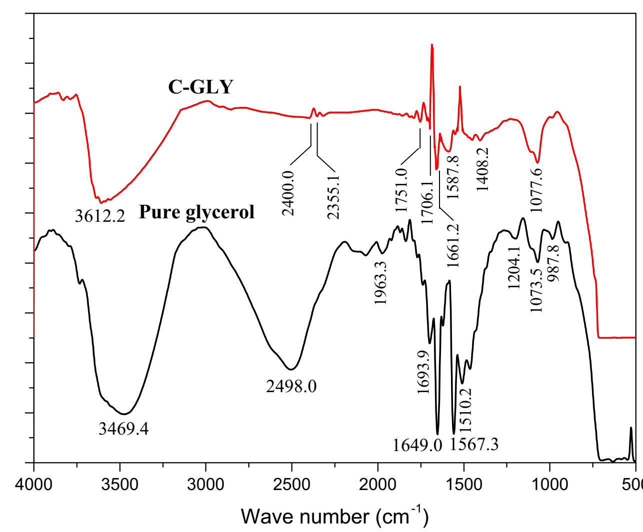

Fig. 2. IR spectra of C-GLY and pure glycerol.

2.2. Methods

2.2.1. Grinding experiment

C-GLY was uniformly dropped on the surface of materials which were to be ground; the dosage of C-GLY grinding aids was 0.08 wt% of the total mass of materials. The weight of materials for each grinding experiment was 3 kg and the grinding time was 10 min, 20 min, 30 min, 40 min, 50 min, 60 min and 70 min, respectively. Then the particle characteristics of ground GBFS were tested.

Table 1
Chemical compositions of GBFS and cement (wt%).

	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	K_2O	Na_2O	SO_3	LOI
GBFS	37.21	31.03	14.28	1.54	9.13	0.59	0.28	0.12	4.57
Cement	65.74	21.17	5.65	2.73	1.75	0.92	0.24	1.08	0.62