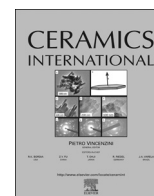




ELSEVIER

Contents lists available at ScienceDirect

Ceramics International

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

Immobilization of chromite ore processing residue with alkali-activated blast furnace slag-based geopolymer

Xiao Huang^{a,1}, Tao Huang^{a,1}, Shan Li^{a,1}, Faheem Muhammad^{a,1}, Guojing Xu^{a,1},
Ziqiang Zhao^{a,1}, Lin Yu^{a,1}, Yujie Yan^{a,1}, Dongwei Li^{a,b,*}, Binquan Jiao^{a,b,*}

^a State Key Laboratory for Coal Mine Disaster Dynamics and Control, Chongqing University, Chongqing 400044, China

^b College of Resource and Environmental Science, Chongqing University, Chongqing 400044, China

ARTICLE INFO

Article history:

Received 25 January 2016

Received in revised form

4 March 2016

Accepted 4 March 2016

Available online 5 March 2016

Keywords:

Blast furnace slag

Alkali-activated

Geopolymer

Chromite ore processing residue

Immobilization

ABSTRACT

Chromite ore processing residue (COPR) is an industrial waste produced in the chromic salts production process and contains a small portion of leached Cr(VI), which is highly toxic and is listed as a hazardous waste. The immobilization of COPR using a blast furnace slag-based geopolymer has been investigated in this study. The optimum parameters for preparing the blast furnace slag-based geopolymer using an orthogonal experiment were obtained. COPR was used to replace the amount of blast furnace slag for the preparation of the geopolymer. The COPR-bearing blast furnace slag-based geopolymer has potential application as a construction material and for geological disposal. The combined effect of physical fixation, adsorption and ion exchange in the geopolymeric and CSH (calcium silicate hydrate) gel is considered to be the main mechanism, and the reduction of S^{2-} in the blast furnace slag played a significant role in the solidification of the COPR.

© 2016 Elsevier Ltd and Techna Group S.r.l. All rights reserved.

1. Introduction

Chromite ore processing residue (COPR) is an industrial solid waste [1]. It has been reported that 2–3 t of COPR is generated in the production of 1 t chromic salts [2]. Accumulation of COPR takes up considerable land, and when the leached hexavalent chromium flows into the water after rainfall, it pollutes the water and the soil and harms human health [3–6]. Chromium exists in the natural environment as Cr^{3+} , CrO_4^{2-} and $Cr_2O_7^{2-}$. Cr^{6+} is a highly soluble and carcinogenic ion. The toxicity of Cr^{6+} is much greater than that of Cr^{3+} , so it is the main toxic substance in COPR [7–10]. In the past, the treatment of COPR focused on the transformation of Cr(VI) to Cr(III) [11–13]. Some success was achieved. For example, COPR was used instead of limestone for smelting iron. However, due to with the significant accumulation of COPR, it is negligible to treat COPR using this method. Currently, solidification/stabilization (S/S) technology is the most commonly approved and applied method. To prevent the diffusion of heavy metals, they are sealed with a solidification agent in a solidified body, which is the main treatment method for heavy metal wastes. In recent years, the most widely used S/S system has been cement-

based materials, but this method has some problems, such as high permeability, high capacity, poor durability and low strength.

With the advantages of high early strength, low density, acid resistance, low permeability and thermostability, geopolymer, as a new type of cementing material, has been the main focus for the immobilization of heavy metals in recent years. Geopolymers are inorganic polymers with clay and aluminum silicate that are generated at low temperatures [14]. The structure of the “type of zeolite” is similar to that of a geopolymer, and the structure is likely confined to a closed cage cavity that can firmly adsorb the metal ion and other toxic substances [15–17]. Geopolymers have been used to immobilize Cu^{2+} , Zn^{2+} , Pb^{2+} and Cd^{2+} , so they have potential for COPR immobilization [18–20]. Recently, due to the large amount of silicon-aluminum components, blast furnace slag (BFS) has become a hot spot in the study of the preparation of geopolymer materials. BFS is the industrial waste from smelting iron [21,22]. After water quenching, most of the compounds have not formed a stable state due to the sharp drop in temperature. The slag retains its structure as a vitreous body and has good activity. According to statistics, 0.3–1 t BFS is generated in the production of 1 t of pig iron. The discharge and accumulation of BFS consumes significant manpower, materials and financial resources and also pollutes the environment. Therefore, the preparation of geopolymers using BFS is of great significance for solid waste utilization, energy savings and emissions reduction [23,24]. Moreover, the presence of BFS can decrease the permeability of the penetrating agents. This characteristic of BFS

* Corresponding authors at: State Key Laboratory for Coal Mine Disaster Dynamics and Control, Chongqing University, Chongqing 400044, China.

E-mail addresses: lironwei@cqu.edu.cn (D. Li), j.binquan@cqu.edu.cn (B. Jiao).

¹ These authors contributed equally to the work.

increases the durability of the geopolymer and supports the long-term capture of heavy metals in the solidified matrix.

The immobilization process of COPR is the focus of this study and includes the properties of the solidified matrix, the leaching concentration of the chromium ion, and the mechanism. Sun T et al. [25] found that the chromium solidified in a geopolymer was more stable than when using cement S/S technology due to the combination of electrostatic attraction and the physical layer. Some studies have suggested that heavy metals could be adsorbed to units of geopolymer and then be locked into the network structure in the geopolymerization process, but this method could not be used for Cr(VI). Zhang JG et al. [26] used cement to solidify COPR, but this technique did not inhibit the leaching of Cr(VI). Bulut U et al. [27] improved the immobilization effect of Cr(VI) by adding ferrous sulfate to the cement. Van Deventer et al. [28] found that alkali-activated fly ash-based geopolymer had good immobilization effect on Cd^{2+} and Pb^{2+} and had strong resistance to Cr(VI) leaching after adding sodium sulfide as a reducing agent. A leaching test was conducted in either deionized water or an acid solution. Kindness A et al. [29] showed that BFS incorporated into the cement can effectively inhibit the leaching of Cr(VI) due to the reducing S^{2-} substances contained in the BFS. These studies show that the reducing conditions in the hydrated BFS pastes (presence of S^{2-} ions) play a positive role in the immobilization process of COPR by mechanisms such as the partial reduction of Cr^{6+} to Cr^{3+} . It is theoretically feasible to use BFS to prepare the geopolymer to solidify COPR. However, many of the exact details of the processes by which heavy metal cations are incorporated into the geopolymer structure are not yet fully understood, so the solidification mechanism also requires further study.

In this paper, alkali-activated BFS-based geopolymer was proposed to solidify COPR. An orthogonal experiment was designed to analyse the factors that influence the properties of the BFS-based geopolymer and to determine the optimum combination. The COPR was immobilized by the geopolymer using partial COPR instead of BFS, and the stability of the solidified body was investigated. X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR) and scanning electron microscopy with energy dispersive spectrometry (SEM-EDS) were used to further analyse the characteristics of the geopolymer and to explore the solidification mechanism of COPR. Moreover, the reaction mechanism and the physical properties were linked.

2. Materials and methods

2.1. Materials

The blast furnace slag (BFS) used in this study was supplied by a steel plant in Chongqing, China. The coefficients of basicity, activity and quality were 1.34, 0.36, 1.63, respectively, and the hydraulic module was 1.96. The chemical composition of the BFS was determined by an X-ray fluorescence spectrometer (XRF, Shimadzu, PerkinElmer) and is shown in Table 1. Chromite ore processing residue (COPR) was obtained from a chemical plant in Chongqing, China. Because of the different raw materials, production processes and formulas, the composition of COPR varies but typically contains Ca, Mg, Cr, Al, Si and Fe. The COPR was dried

Table 1
The chemical composition of BFS (w%).

CaO	SiO ₂	Al ₂ O ₃	MgO	TiO ₂	SO ₃	Fe ₂ O ₃	K ₂ O	Na ₂ O	LOI ^a
40.43	30.18	10.77	7.91	6.01	3.21	0.64	0.56	0.28	0.01

LOI^a: Loss on ignition at 1000 °C.

Table 2
The chemical composition of COPR (w%).

CaO	SiO ₂	Al ₂ O ₃	MgO	TiO ₂	Fe ₂ O ₃	Na ₂ O	ZnO	Cr ₂ O ₃	LOI ^a
0.69	6.19	11.40	15.13	1.26	47.16	5.64	0.18	12.34	0.01

LOI^a: Loss on ignition at 1000 °C.

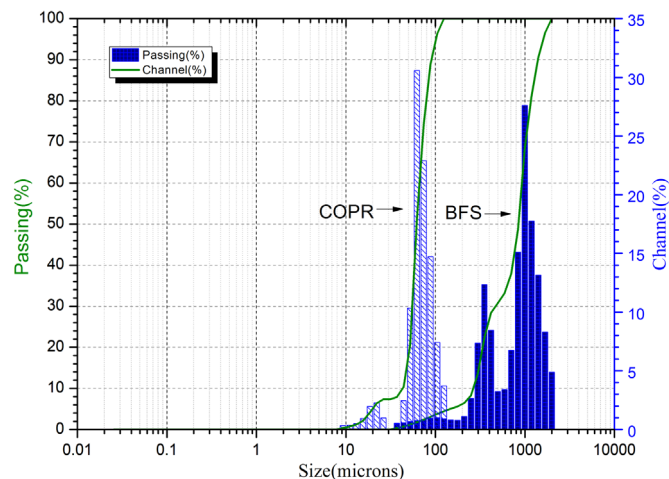


Fig. 1. The particle size distribution of the raw materials.

in an oven at 100 °C, milled in a ball-grinding mill and then passed through a 200-mesh sieve. The chemical composition of COPR is shown in Table 2. The particle size distribution of the raw materials is described in Fig. 1.

For the alkali activator, the water glass was industrial grade, and the modulus was 3. NaOH was analytical grade.

All experiments were performed using the same batch of reagents and starting materials, and distilled water was used throughout the experiment.

2.2.1. Methods

2.2.1. The grinding of BFS

A laboratory ball-grinding mill was used to grind the BFS sample. The speed of the ball-mill was 250 rpm, and the mass ratio of the material to the balls was 1:6. All BFS samples were divided into batches for grinding.

2.2.2. Specimen preparation

After grinding and drying, a certain proportion of the BFS was placed in a mixer. The alkali activator solution was obtained from NaOH and water glass dissolved in deionized water and cooled to room temperature. Then, BFS was added to the alkali activator solution and was stirred for 10 min until a homogeneous colloid formed. The colloid was poured into 20 mm × 20 mm × 20 mm cube molds and was vibrated for 3 min to remove air bubbles. A polyethylene (PE) film covered the opening surface of the mold to prevent the evaporation of water. The mold was placed in a curing box with a constant temperature of 25 °C and 90% relative humidity. After 24 h, the sample was demolded and maintained for a specified period.

2.2.3. Compressive strength measurement

The compressive strengths of the geopolymers were tested according to standard GB/T 17671–1999 [30] on a universal testing machine (AGN-250, Shimadzu, Japan). The standard deviation of each set of samples was approximately 10%; the value of the compressive strength was taken from the average of three parallel

Download English Version:

<https://daneshyari.com/en/article/1459023>

Download Persian Version:

<https://daneshyari.com/article/1459023>

[Daneshyari.com](https://daneshyari.com)