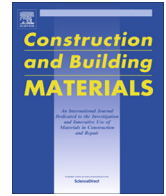




Contents lists available at ScienceDirect

Construction and Building Materials

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

Advances in understanding and analyzing the anti-diffusion behavior in complete carbonation zone of MSWI bottom ash-based alkali-activated concrete

Guodong Huang^{a,b,c}, Yongsheng Ji^{a,c,*}, Linglei Zhang^{a,c}, Jun Li^{a,c}, Zhihui Hou^{a,c}^a State Key Laboratory for Geomechanics and Deep Underground Engineering, China University of Mining and Technology, Xuzhou 21116, Jiangsu, China^b School of Civil Engineering and Construction, Anhui University of Science and Technology, Huainan 232001, Anhui, China^c School of Mechanics and Civil Engineering, China University of Mining and Technology, Xuzhou 21116, Jiangsu, China

HIGHLIGHTS

- BA displayed a unique anti-diffusion behavior under natural conditions.
- The anti-diffusion behavior was influenced by amount of sodium silicate used.
- Anti-diffusion effect of BA significantly reinforced its carbonation resistance.

ARTICLE INFO

Article history:

Received 17 January 2018

Received in revised form 7 July 2018

Accepted 7 August 2018

Keywords:

Carbonation
Municipal solid waste incineration bottom ash
Alkali-activated
Anti-diffusion
Concrete

ABSTRACT

This study investigated the carbonation resistance of municipal solid waste incinerator (MSWI) bottom ash alkali-activated concrete (BA) and Portland cement concrete (CC) through the accelerated carbonation test. The results show that BA has lower resistance against carbonation compared to CC under the conditions of the accelerated carbonation experiment. However, BA displayed a unique anti-diffusion behavior under natural conditions which significantly reinforced its carbonation resistance. The anti-diffusion behavior was closely related to the amount of liquid sodium silicate in the activator. Moreover, the pH value in complete carbonation zone of BA was much higher compared to that of CC. The main reason is that liquid sodium silicate turned into magadiite in BA and then the magadiite turned back to liquid sodium silicate to release a large amount of OH⁻ under low concentrations of CO₂. This resulted in a rapid increase in pH value of the pore fluid and generation of the anti-diffusion behavior.

© 2018 Published by Elsevier Ltd.

1. Introduction

Alkali-activated materials are inorganic nonmetallic compounds which are prepared by the action of strong alkali on industrial solid wastes consisting of aluminosilicates [1]. Compared to conventional Portland cement materials, alkali-activated materials have good mechanical performance, high temperature resistance, resistance against acids, alkali, and salts, and low permeability. Moreover, the production of alkali-activated materials does not require high temperature calcination or sintering processes unlike the production of Portland cement. Alkali-activated materials can also undergo complete polymerization at room temperature

[2–4]. Furthermore, alkali-activated materials have lower energy consumption, almost no pollution, and are easy to recycle and reuse [4–6]. Therefore, they are environmentally friendly green materials which may be used as a building material to replace Portland cement in the future [7–10].

However, studies on the durability of alkali-activated materials have found that the carbonation resistance of alkali-activated concrete is weaker than that of Portland cement concrete, particularly under the conditions of accelerated carbonation test. Laboratory tests of alkali-activated concrete have shown relatively high carbonation rates and this problem is more serious as the concentration of CO₂ increases [11]. The current research indicates that due to a certain concentration of CO₂ in the atmosphere, it enters into reinforced Portland cement concrete via diffusion and dissolves in the pore liquid, lowering its pH value. The steady decrease in pH value of the pore fluid will cause the deactivated film of reinforcing bar to become unstable and even damaged, resulting in accelerated

* Corresponding author at: State Key Laboratory for Geomechanics and Deep Underground Engineering, China University of Mining and Technology, Xuzhou 21116, Jiangsu, China.

E-mail address: jysbh@126.com (Y. Ji).

corrosion of the rebar and then a reduction in bearing capacity [12]. Therefore, rebar corrosion due to carbonation is a common problem for the ordinary Portland cement (OPC) system, particularly in warm and relatively humid environments. Moreover, alkali-activated materials have higher carbonation rates than Portland cement concrete, which makes them more prone to rebar corrosion issues due to carbonation.

Several studies have investigated the carbonation of alkali-activated slag (AAS) concrete and other related alkali-activated materials [13]. These studies indicate that alkali-activated concrete exhibits a higher carbonation rate than Portland cement concrete at the same compressive strength and that the carbonation mechanism for the two materials is different [14]. Moreover, some studies have shown that the higher carbonation rate of alkali-activated materials results in the degradation of its mechanical properties, although there is some controversy about this [15–17]. However, other studies have found results that are contrary to the reports of carbonation problems in alkali-activated mortars and concretes, as mentioned above [18]. These studies have experimentally demonstrated that alkali-activated concretes removed from accelerated carbonation test after extended periods do not display carbonation issues [19]. This indicates that the outcome of the accelerated test is not an accurate predictor of in-service performance of alkali-activated materials and the carbonation resistance of alkali-activated materials in natural carbonation is equivalent to that of Portland cement concrete [20]. The researchers pointed out that the change in pore solution equilibria causes the formation of sodium bicarbonates during accelerated carbonation, compared to the hydrous sodium carbonates formed during natural carbonation [21]. This shifts the carbonation mechanism to favor more rapid reaction progress, and results in a higher apparent degree of acceleration (compared to natural conditions) than in Portland cements [14].

Shi et al. reported that the natural carbonation rates for alkali silicate-activated slag concretes are lower than 1 mm/year, while laboratory studies have shown that carbonation depths in alkali-activated concretes range from 13 mm to 25 mm after 240 h of exposure to 7% CO₂ [18]. Xu et al. studied aged concretes (up to 35 years) based on slag activated with carbonates or carbonate/hydroxide blends, and observed an acceptable carbonation rate for all samples (0.03–0.5 mm/year), verifying the high stability of these AAS binders [22,23]. Bernal et al. believe that accelerated carbonation testing is unduly aggressive towards alkali-activated concretes, and test results must be cautiously interpreted [14,15,19,20]. Therefore, there is a need for reasonable evaluation of carbonation resistance for predicting the service life of alkali-activated concrete under carbonating conditions. The main factors affecting carbon resistance in alkali-activated materials need to be

analyzed by studying the carbonation process and the change in the product before and after carbonation.

This study focuses on evaluating the effect of accelerated carbonation on alkali-activated concrete produced mainly by MSWI bottom ash, and the improvement in carbonation resistance due to anti-diffusion behavior in carbonation zone. The anti-diffusion behavior refers to the automatic alkaline recovery in the complete carbonation zone of alkali-activated concrete when removed from the accelerated carbonation chamber. By macroscopically studying the anti-diffusion behavior in carbonation zone and by microstructural analysis (Fourier Transform Infrared Spectroscopy (FT-IR) and X-ray diffraction (XRD)) of the products before and after carbonation, we can elaborate on the mechanism of anti-diffusion behavior occurring in alkali-activated materials and perform a reasonable evaluation of their carbonation resistance.

2. Experimental materials and methods

2.1. Materials

(1) MSWI bottom ash

The MSWI bottom ash used in this experiment was supplied by GCL-Poly (Xuzhou, China) Renewable Energy Power Generation Co., Ltd. The municipal solid waste was first separated via magnetic separation and then calcined at 800 °C. The bottom ash was washed at the recycle station and its chemical composition is shown in Table 1. In this experiment, the bottom ash was ground into a fine powder with surface area and specific gravity of 400 m²/kg and 2.47, respectively. The particles were mainly spherical with a median particle size of 47 μm and 28% was retained on a 45 μm sieve.

(2) Granulated blast furnace slag (GBFS) and slaked lime

The GBFS used in the experiment is S95 granulated blast furnace slag powder, which conforms to the Chinese standard GB/T 18046-2008 [24]. The surface area and specific gravity of GBFS are 416 m²/kg and 2.89, respectively, and 35% was retained on a 45 μm sieve. Its chemical composition is also shown in Table 1. Industrial grade slaked lime was used. Its purity is 95%, specific gravity is 2.24, and surface area is 400 m²/kg.

(3) Activator

Sodium hydroxide (NaOH) and sodium silicate solution (Na₂SiO₃) with 9.65% Na₂O, 25.22% SiO₂, and 65.13% H₂O were used as the activators. The sodium silicate solution has a modulus (molar ratio of SiO₂ and Na₂O in liquid sodium silicate) of 2.6. A 4.8 M NaOH solution (NaOH dosage and water content are given in Table 2) was prepared and this solution was used to obtain each set of concrete samples. The NaOH solution was allowed to stand for 24 h before use.

(4) Others

The Portland cement used for the experiment was the P·O 42.5 type, which conforms to the Chinese standard GB 175-2007 [25]. Commercially available limestone with a maximum size of 30 mm and a specific gravity of 2.67 in saturated surface

Table 1
Chemical composition of raw material (%).

Raw material	SiO ₂	CaO	Al ₂ O ₃	Fe ₂ O ₃	MgO	K ₂ O	Na ₂ O	Zn, Pb, Ba, Sr, Cu	Loss
GBFS	31.35	34.65	18.65	0.57	9.31	–	–	–	0.7
Cement	26.55	62.9	7.77	3.62	2.68	1.5	0.31	–	3.2
MSWI bottom ash	43.82	24.44	14.18	6.18	3.26	2.52	2.24	0.61	1.62

Table 2
Mix proportion of the concrete kg/m³.

	cement	MSWI bottom ash	GBFS	Ca(OH) ₂	water	sodium silicate solution	NaOH	sand	gravel	compressive strength (MPa 28 d)
C-1	330	0	0	0	165	0	0	651	1056	45.2
C-2	0	165	132	33	92.4	88	17.6	651	1056	49.6
C-3	0	165	132	33	133.3	0	31.7	651	1056	46.7
C-4	0	165	132	33	0	254	0	651	1056	18.5

Note: For example (C-2), Dissolve 17.6 kg of NaOH into 92.4 kg of water, which the molar solubility of NaOH solution is 4.8 M.

Download English Version:

<https://daneshyari.com/en/article/11001046>

Download Persian Version:

<https://daneshyari.com/article/11001046>

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