



Solidification of nitrate solutions with alkali-activated slag and slag–metakaolin cements



Nailia R. Rakhimova^{a,*,1}, Ravil Z. Rakhimov^a, Yury N. Osin^b, Natalia I. Naumkina^c, Alfiya M. Gubaidullina^c, Grigory I. Yakovlev^d, Arina V. Shaybadullina^d

^a Kazan State University of Architecture and Engineering, Kazan, Russian Federation

^b Kazan Federal University, Kazan, Russian Federation

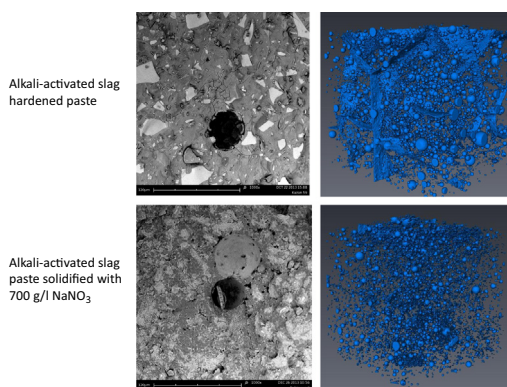
^c Central Research Institute for Geology of Industrial Minerals, Kazan, Russian Federation

^d Kalashnikov Izhevsk State Technical University, Izhevsk, Russian Federation

HIGHLIGHTS

- The effectiveness of an AASC matrix for NaNO_3 solution solidification is stated.
- XRD, DTA-TG, and X-ray microtomography experiments were performed.
- Crystallization of NaNO_3 reduces the shrinkage of hardened AASC-based waste forms.
- Metakaolin shortens the setting time and increases the compressive strength of AASC.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:

Received 16 August 2014

Accepted 18 November 2014

Available online 26 November 2014

ABSTRACT

The solidification of nitrate solutions with alkali-activated slag (AASC) and slag–metakaolin cements (AASMC) and the resulting setting times, compressive strengths, dimensional stability, water resistance, hydration products, microstructures, and macroporous network structures were evaluated. The influences of the alkali activator concentration, mineral composition of metakaolin, ratio of slag to slag + metakaolin, and concentration of NaNO_3 on the cement performance were all evaluated in detail. The compressive strength of cemented nitrate solutions with AASC and AASMC aged for 28 days was from 13.4 to 42 MPa depending on the NaNO_3 concentration. X-ray diffractometer, differential thermal analyzer, and electron microscope analyses suggested that NaNO_3 crystallizes in cementitious matrices without reacting with the hydration products of AASC and AASMC. X-ray microtomography showed that the solidified NaNO_3 solution with a salt concentration of 700 g/l and AASC had a denser microstructure without shrinkage microcracks, a smaller macropore volume, and smaller macropore sizes than hardened AASC-based paste mixed with water.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

There is a wide variety of alternative or non-traditional cements that significantly differ from ordinary Portland cement (PC) and from each other in terms of their composition and type of the

* Corresponding author.

E-mail address: rahimova.07@list.ru (N.R. Rakhimova).

¹ Presenting author.

raw materials, the nature of their hardened products, and their mechanism of hardened cement paste formation. Accordingly, each alternative cement has a different history of research, adoption, and application, and such variety provides many opportunities for specific applications. For example, many studies [1–13] have examined the effectiveness of different cements for the immobilization of toxic or radioactive waste. In particular, the lower solubility and slower ion exchange, different pH, faster hardening, and lower permeability of the hardened pastes of certain alternative cements, among their other properties, have allowed alternative binders ‘to push the envelope’ of cementation technology beyond ordinary PC for toxic and radioactive waste handling. Such binders in some cases exhibit higher efficiency for both physical isolation and chemical binding of heavy metals and radionuclides and have widened the range of wastes that can be immobilised by cementation. Furthermore, they have allowed waste cementation technology to be optimized for certain problematic waste components through faster curing of the cementitious waste forms or elimination of the need for pretreatment of the waste. Finally, alternative binders could also act as adsorbents and chemical additives, as well as immobilization agents.

However, the corrosion resistance and durability of materials based on alternative cements requires further improvement before they can be widely used for the immobilization of toxic waste. For this purpose, the introduction of chemical and mineral admixtures is a promising approach.

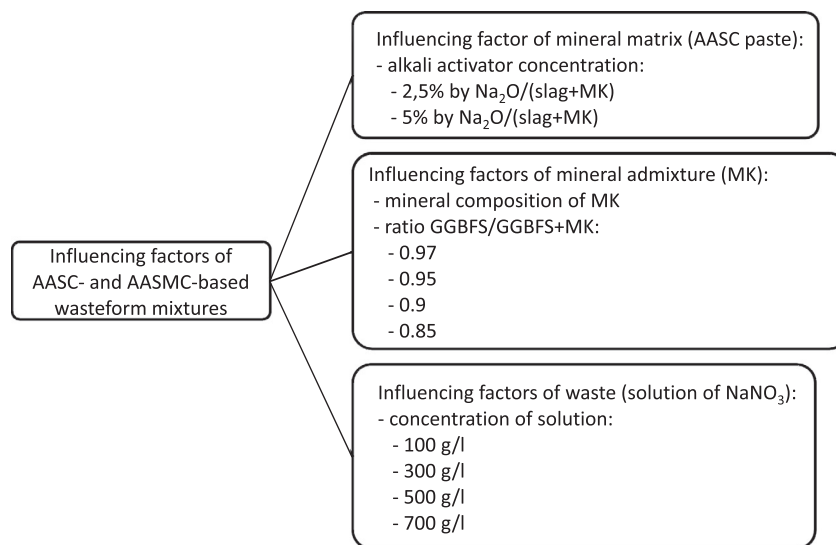
1.1. Alkali-activated slag and slag–metakaolin cements

Alkali-activated slag–cement (AASC), which is obtained through alkali activation of ground–granulated blast furnace slag (GGBFS), is one alternative binder that has the potential to be applied as a matrix for stabilization/solidification of hazardous and radioactive wastes [14–20]. The primary binder phase of AASC is an aluminum–modified calcium silicate hydrate C–(A)–S–H gel that is amorphous to partially crystalline, is relatively highly cross–linked, has a moderate degree of Al substitution, and has a low Ca/Si ratio [21–23]. Alkali activation not only efficiently produces AASCs in the matrices, but also allows effective interaction between the AASC paste and fillers. Thus, this technique is compatible with mineral blending of materials with various compositions and

structures. For this reason, a much wider range of mineral materials can be used in AASCs than in blended PCs [24,25].

Metakaolin (MK) is one multipurpose mineral that has been admixed in both PC [26–30] and AASC [31–33] for the cementation of toxic and radioactive wastes. The alkali activation of slag–MK mixtures results in the simultaneous formation of calcium silicate hydrate C–S–H and sodium aluminosilicate hydrate N–A–S–H gels in the form of C–S–H/N–A–S–H [34–36] or C–N–(A)–S–H/N–A–S–H [37], which improves the performance of the blended binders. The effect of MK on the strength characteristics of hardened pastes depends on the nature and concentration of the alkali activator. Burciaga–Díaz et al. [37] found that hardened AASC paste exhibited the highest compressive strength when 5% Na₂O was added, whilst unblended MK and GGBFS/MK (20/80) pastes required 15% Na₂O to reach the highest compressive strength. The influence of the GGBFS/MK ratio on the strength of the mixed cements has mostly been examined for pastes consisting of a combination of sodium silicate and NaOH solutions. Yip et al. [35], Bernal et al. [38,39], Burciaga–Díaz et al. [40], and Yunsheng et al. [32] have reported the strength improvement of hardened pastes at concentrations of 20–40% MK. Bernal also reported [41] that increasing the MK content to 20% and raising the activator concentration led, in most cases, to reductions in water absorption and water sorptivity and decreases in chloride permeability.

Guangren et al. [31] studied the effect of MK on the immobilization behavior of an AASC–based matrix for simulated radioactive Sr or Cs. The addition of MK provided AASC–based matrix with excellent selective Sr and Cs adsorption properties. Compared to the PC matrix and AASC–based matrix, the matrix based on AASC with 10% MK and 20% clay adsorbents exhibited the highest distribution ratio K_d (ratio of the amount of ions adsorbed by a unit mass of solid adsorbent to the equilibrium concentration of the ion in the aqueous phase) and the lowest leaching rates of both Sr and Cs ions. The addition of MK favors the formation of (Al + Na)–substituted CSH and a self–generated zeolitic precursor in the AASC–based matrix. These hydration products exhibited better selective adsorption and cation exchange capacity for Sr and Cs ions. It was also found that the MK–doped AASC–based matrix and unblended AASC–based matrix possessed similar pore structures. Their pore size distributions were concentrated around small pores (<10 nm), which represented over 80% of the porosity. The



Influencing factors of mineral matrix (AASC and AASMC pastes)

Fig. 1. Variable influencing factors of AASC- and AASMC-waste form mixtures.

Download English Version:

<https://daneshyari.com/en/article/1565043>

Download Persian Version:

<https://daneshyari.com/article/1565043>

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