



Influence of slag chemistry on the hydration of alkali-activated blast-furnace slag – Part I: Effect of MgO

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ARTICLE INFO

Article history:

Received 14 February 2011

Accepted 3 May 2011

Keywords:

Alkali activated slags D

MgO (D)

Hydration mechanisms A

Microstructure (B)

Mechanical strength C

ABSTRACT

The hydration and the microstructure of three alkali activated slags (AAS) with MgO contents between 8 and 13 wt.% are investigated. The slags were hydrated in the presence of two different alkaline activators, NaOH and $\text{Na}_2\text{SiO}_3 \cdot 5\text{H}_2\text{O}$ (WG). Higher MgO content of the slag resulted in a faster reaction and higher compressive strengths during the first days. The formation of C(–A)–S–H and of a hydrotalcite-like phase was observed in all samples by X-ray diffraction (XRD), thermal analysis (TGA) and scanning electron microscopy (SEM) techniques. Increasing the MgO content of the slag from 8 to 13% increased the amount of hydrotalcite and lowered the Al uptake by C–S–H resulting in 9% higher volume of the hydrates and a 50 to 80% increase of the compressive strength after 28 days and longer for WG activated slag pastes. For NaOH activated slags only a slight increase of the compressive strength was measured.

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1. Introduction

Alkali-activated binders based on ground granulated blast-furnace slag represent a viable and sustainable alternative to Portland cement since they use by-products of other industrial manufacturing processes. If one ton of slag replaces one ton of clinker, about 800 kg of CO_2 emissions can be “saved” [1,2]. Thus, the use of slag has important economical and environmental implications. Although a large proportion of global slag is used by the building industry, there is still a proportion remaining which is not yet used due to insufficient reactivity. The easiness of activation and the hydration of the slags depend mainly upon the mineralogical composition and fineness of the slag and on the type of the alkaline activator used. The addition of alkalis stimulates the dissolution of the slag and thus the formation of hydration products, mainly calcium silicate hydrates incorporating significant amounts of aluminium (C(–A)–S–H), hydrotalcite-like phase and strätlingite [3–5]. Activated slag systems often exhibit a rapid strength development, and using the adequate activators can lead to rapid setting, good durability and high resistance to chemical attack [6–8].

Many aspects of the chemistry of slag hydration activated by alkali still need to be explored, impeding the solution of the remaining practical problems and obstructing a wider application of this kind of binder. Probably most studies on AAS are focussed on the activator and not on slag chemistry. Knowing that “good slags” (=easily activated in a cementitious environment) are already largely used, a

better understanding of the effects of the chemical composition of the slag could indicate ways to use less reactive slags efficiently. Understanding the hydration and development of the microstructure is the key to understand the performance of slags. Questions regarding the influence of different components such as mineral additions or slag composition on the hydration process and mechanical strength are of great interest as they have a major impact on the applicability of any construction material. The present study aims to investigate the effect of the MgO content in the slag on the kinetics of slag reaction and on compressive strength.

Experimental studies on the effect of MgO on slags are rare. In the iron-making process, the slag–iron interfacial tension was found to slightly increase with increasing MgO content in the slag [9]. It was reported that the MgO content of slag has a beneficial effect on the soundness of the autoclaved Portland cement–slag blends if the MgO was bound in non reactive phases such as merwinite, but was harmful for autoclaved cements when MgO was present as more reactive periclase [10].

An investigation, where 30% Portland cement was blended with 5.4% of anhydrite plus gypsum and 65% of different granulated blastfurnace slags, observed that the highest compressive strength of the mortars was measured at high Al_2O_3 and low $\text{MgO}/\text{Al}_2\text{O}_3$, i.e. where a high quantity of ettringite formed and little hydrotalcite [11]. In alkali activated slag systems, it has been reported that a small amount of crystalline phases in the slags and/or more MgO increased the compressive strength, whilst the presence of more Al_2O_3 had a negative effect [12].

The present study aims to investigate the effect of MgO on the hydration properties of alkali activated slag over 1 year, using three slags with different MgO contents whilst the contents of the other oxides are nearly constant. Sodium silicate and sodium hydroxide are

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