Construction and Building Materials 156 (2017) 1019–1027

Contents lists available at ScienceDirect

Construction and Building Materials

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

Effect of saline admixtures on mechanical and microstructural properties of cementitious matrices containing tailings

Babak Koohestani *

Mineral Processing and Environmental Department, Tarbiat Modares University, Tehran, Iran
Université du Québec en Abitibi-Témiscamingue, 445 Boul. de l'Université, Rouyn-Noranda, Québec J9X 5E4, Canada

HIGHLIGHTS

- The use of Methyl-silane in cementitious materials is investigated.
- The addition of colloidal nano-silica in cementitious materials is evaluated.
- Methyl-silane is efficient to decrease the water to cement ratio.
- Methyl-silane improved the total performance of cementitious materials.

ARTICLE INFO

Article history:
Received 3 May 2017
Received in revised form 31 August 2017
Accepted 11 September 2017

Keywords:
Cement-based materials
Silane
Nano-silica
Mine tailings
Cement hydration
Thermogravimetric analysis
Porosimetry
C-S-H gels

ABSTRACT

The addition of silane coupling agents as an additive in cement-based materials provides several technical, operational, and economic advantages such as a reduction in the amount of water to cement ratio and an improvement in flow behavior. In this study, we used mine tailings as the sole source of fine aggregates along with two different silane agents, namely methyl-trimethoxy silane or MTMS as a water repellent and dispersing agent and tetraethyl-orthosilicate or TEOS as the precursor of nano-silica. Based on the achieved results, the addition of 1% MTMS decreased the water requirement of cement and tailings mixture up to 25% for a specific slump height while the strength acquisition was mainly under the influence of MTMS rather than TEOS. The addition of these silane agents to the cementitious matrix containing tailings improved the matrix densification by filling influence of fine pores and formation of new sources of hydrated cement minerals such as C-S-H gels as discussed in differential thermogravimetric, mercury intrusion porosimetry, infrared spectroscopy, and scanning electron microscopy sections.

1. Introduction

The use of nano-particles such as nano silica in cementitious materials accelerates the hydration process by pozzolanic reaction and densifies the total structure by filling the fine pores and voids between the aggregates and cement hydration products [1–3]. Nano-particles have a high specific surface and react with calcium hydroxide (CH) to form calcium silicate hydrate (C-S-H) gel through the pozzolanic reaction [4,5]. It is reported that the maximum pozzolanic reaction occurs at early ages of cement hydration and hence the early strength development increases [6,7]. On the other hand, if not being dispersed properly, nano-particles agglomerate and retard the strength development of cementitious materials. The addition of water-repellent chemicals improves the dispersion of nano-particles particularly when used in the colloidal form (e.g., TEOS or tetraethyl orthosilicate) [8]. The formation of nano-silica from TEOS occurs due to hydrolysis and condensation (sol-gel process) as illustrated in Fig. 1a [9,10] and the typical pozzolanic reaction of TEOS and CH is displayed in Fig. 1b [11].

A silane is called organo-functional (organosilane) if an organic group is attached to the silicon molecule directly or through the organic bridges (i.e., alkyls) to create organic reactivity. Methyl-trimethoxy silane (MTMS) consists of a non-hydrolysable and covalently bonded methyl group that provides water repellency effect to the silicon molecule and broadly used as a co-precursor with TEOS [12–14]. Fig. 2a displays the sol–gel process of methyl-silane. The produced silanol groups from the hydrolysis of TEOS (Fig. 1a) and MTMS (Fig. 2a) react and form a highly reactive silanol (SiOH) networks that later will condense and establish a three-dimensional silica network (siloxane or Si-O-Si) (Fig. 2b). Therefore, a highly dispersed and homogeneous system of organic-inorganic phase can be formed due to the steric repulsive

* Address: Mineral Processing and Environmental Department, Tarbiat Modares University, Tehran, Iran.
E-mail address: Koohestani.ba@gmail.com

http://dx.doi.org/10.1016/j.conbuildmat.2017.09.048
0950-0618/

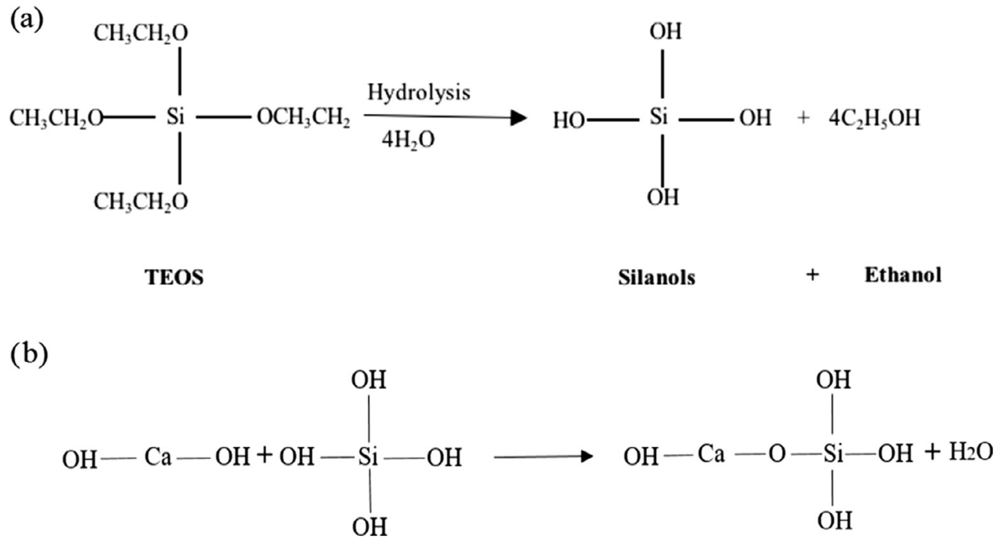

Fig. 1. a) Chemical reaction scheme of Tetraethyl-Orthosilicate, b) Typical pozzolanic reaction of TEOS and CH.

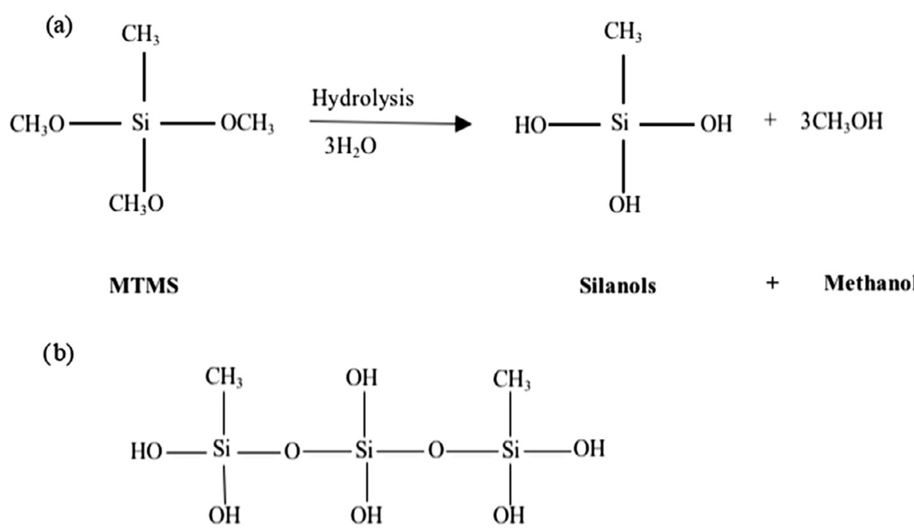

Fig. 2. a) Hydrolysis of MTMS, b) Typical condensed form of TEOS and MTMS.

influence of methyl group that prevents the nano-particles to agglomerate [15–18]. Such linkages also decrease the tendency of the structural phase separation while improve the mechanical strength development of cementitious materials [13,19].

As an enriched source of minerals that produced as the by-product (waste) of mineral processing, mine tailings contains silicates, oxides, carbonates, hydroxides, and sulfides and generally stored in tailings ponds [20]. Different researchers attempted to recover and legitimate the use mine tailings in several applications because of surface waste storage reduction, availability, and low price. [21–23]. The use of mine tailings as a complementary additive in cement-based materials is also reported to be beneficial [24]. In mining industries, Portland cement is regularly mixed with mine tailings while the prepared mixture transferred to the mine voids and extracted stopes for the purpose of filling and stability improvement; this type of mine tailings management known as cemented paste backfill [25–28]. However, due to the various types of existing minerals in mine tailings, some chemical interactions may occur between the hydrated cement minerals such as calcium hydroxide or CH as the second major hydration product of cement and tailings minerals. For example, the oxidized sulfidic minerals (e.g., pyrite) in tailings may react with CH and produce secondary and expansive minerals such as gypsum and ettringite known as sulfate attack [22,23,25]. In addition, the particle size distribution of tailings could have an essential role in the total performance of cement-based matrices [29,30].

Considering this, the use of mine tailings as the fine aggregate along with cement is investigated in this study and the influence of silane admixtures in this case is also scrutinized. In fact, there is a lack of study on the water repellency and strength development influence of different silane agents in cement-based materials containing tailings. The addition of small amounts of silane admixtures may improve the performance of cementitious materials by reducing the water to cement ratio, increase the matrix densification, improve the total flowability and slump height, and accelerate the hydration of Portland cement. Such study deepens our understanding in the field of cementitious materials and mining waste management.

2. Experimental studies

2.1. Materials

In this study, we used a sulfidic (LA, specific gravity = 3.7) and a non-sulfidic (GOL, specific gravity = 2.6) mine tailings. The particle size distributions of both tailings estimated by laser particle size