Construction and Building Materials 166 (2018) 110–117

Contents lists available at ScienceDirect

Construction and Building Materials

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

Effects of quartz-based mine tailings on characteristics and leaching behavior of ultra-high performance concrete

Sukhoon Pyo [a], Million Tafesse [b], Bong-Ju Kim [c], Hyeong-Ki Kim [b,*]

[a] Korea Railroad Research Institute, 176 Railroad Museum Road, Uiwang-si, Gyeonggi-do 16105, South Korea
[b] School of Architecture, Chosun University, 309 Pilmun-daero, Dong-gu, Gwangju 61452, South Korea
[c] Department of Earth and Environmental Sciences, Korea University, Seoul 02841, South Korea

HIGHLIGHTS

- Mine tailings could substitute silica powder and sand in UHPC.
- Characteristics of UHPC were varied by the shape and size of tailings.
- Leaching of toxic elements in tailings was highly controlled by UHPC matrix.

ARTICLE INFO

Article history:
Received 13 December 2016
Received in revised form 11 December 2017
Accepted 17 January 2018
Available online 22 February 2018

Keywords:
Mine tailings
Ultra-high performance concrete (UHPC)
Leaching
Toxicity characteristic leaching procedure (TCLP)
Compressive strength
Flowability
Capillary water absorption

ABSTRACT

High production cost and scarcity of raw materials may hinder the application and accessibility of ultra-high performance concrete (UHPC). In the present study, mine tailings, mineral waste products from mining sites, were applied to mitigate these problems. Two types of quartz-based mine tailings produced in South Korea were used to substitute silica powder and silica sand by half and fully in UHPC. The characteristics of UHPC with the tailings, including the compressive strength, workability, water absorption, and leachability of toxic elements, were experimentally evaluated. The effects of the tailings on the characteristics of UHPC varied according to the shape and size of particles of the tailings. The leaching of toxic trace elements from the tailings was highly controlled due to the chemical and physical capsulation of UHPC.

1. Introduction

Ultra high performance concrete (UHPC) is mostly known for its remarkable strength both in compression and tension, generally above 150 MPa and 5 MPa, respectively, which is achieved through dense particle packing, reducing the water-cement ratio, and using adequate reinforcing fibers. UHPC has additional engineering merits such as high durability, workability, and impact resistance [1,2]. However, UHPC has a very high production cost, thus impeding broad application and accessibility [3,4,5]. In some countries and locations, some raw materials for UHPC such as silica fume, silica powders, silica sand, superplasticizer, and steel fibers are not produced and/or are difficult to obtain due to high transportation costs. Although it varies by location, the general cost of commercially available UHPC is 20–30 times greater than that of conventional concrete with a strength range from 20 to 30 MPa [4].

A number of studies have been carried out to lower the cost of UHPC by using different approaches. Allena and Newtson [5] applied a local sand produced by a size-control process without any pre-treatment as a substitute for pure silica sand in UHPC. Yang et al. [7] used recycled glass cullet and two types of natural sands for UHPC, and they found that these materials resulted in reduced flowability and weakened mechanical properties. Fidjestol et al. [6] also used a local sand and fly ash to fabricate UHPC, and a particle packing theory was applied to obtain the optimal proportion of these materials. Kim et al. [8] used high-volume ground blast furnace slag and rapid-cooling electric arc furnace oxidizing slag to substitute for cement and silica sand, respectively. Pyo and Kim [9] applied coal bottom ash and nano-slag powder as replacements of silica powder. They concluded that, although the industrial by-products reduced the compressive strength slightly

* Corresponding author.
E-mail address: hyeongki@chosun.ac.kr (H.-K. Kim).

https://doi.org/10.1016/j.conbuildmat.2018.01.087
0950-0618/

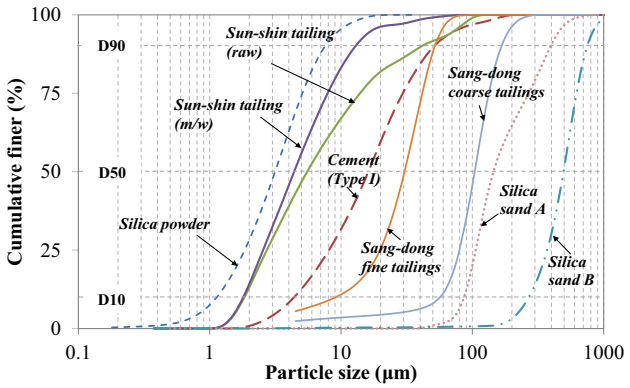


Fig. 1. Particle size distribution of powder materials for UHPC mixtures.

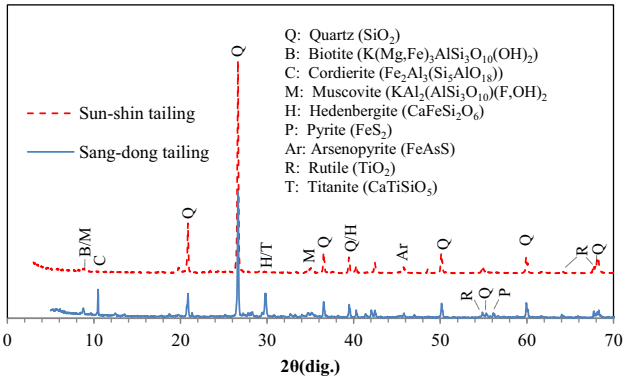
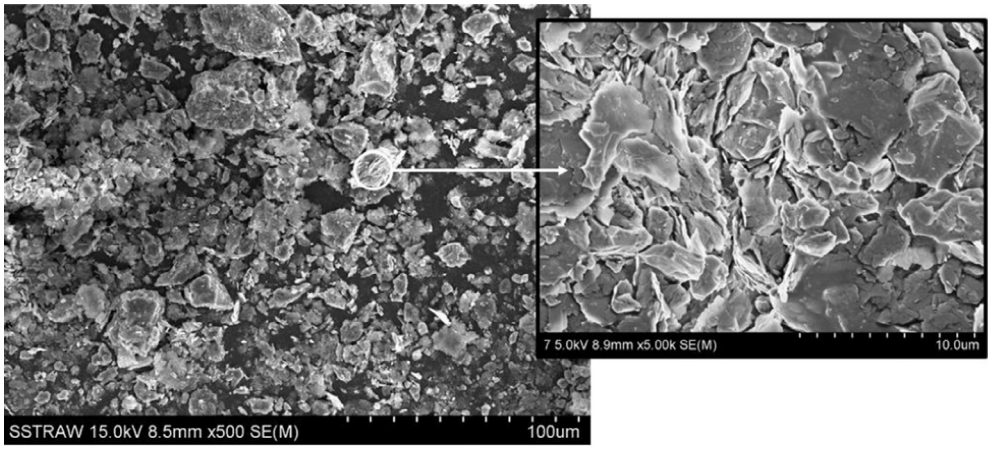


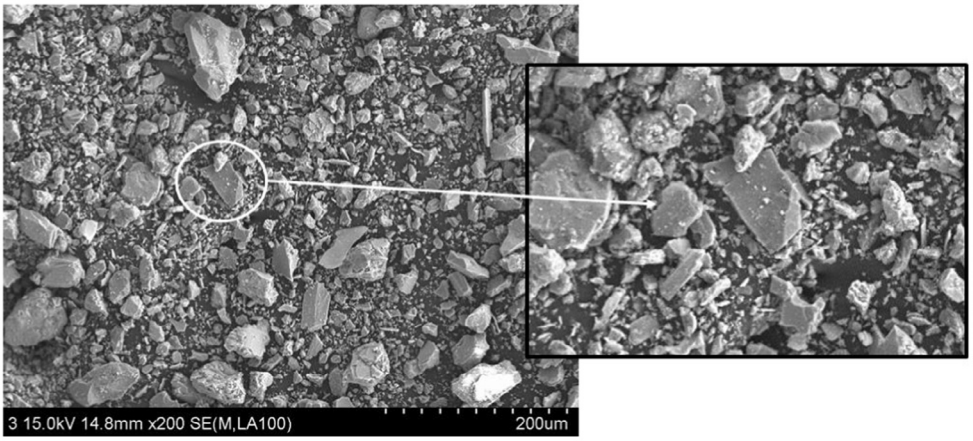
Fig. 2. X- ray diffraction (XRD) spectra of tailings.

at an early age, they yielded considerable improvement in the workability of UHPC.

Along with these, mine tailings, mineral waste products from mining sites, were utilized in the present study to decrease the production cost of UHPC. Mine tailings are a residual product after the separation process of the valuable fraction from the ore. Their particle sizes are very small due to the comminution process, i.e., grinding of ore into fine particles to extract the valuable fraction. In general, when the target elements are rarer and more expensive such as gold and rare earth elements, the particle size of tailings become finer [10]. Because the particle size range of typical tailings is similar to that of binders and fillers in UHPC, such as cement, silica powder, and silica sand, it is possible to replace these constituents using tailings. Moreover, the crystalline structures of some tailings obtained from quartz-based ores are almost equivalent to silica powder and silica sand. It should be noted that, for producing silica powder, milling the silica sand is necessary, which requires substantial energy and cost. Replacing the silica powder



(a)



(b)

Fig. 3. Particle images of Sun-shin tailings at raw state (a) and Sang-dong tailings (b).