Engineering Science and Technology, an International Journal 19 (2016) 970–979

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Contents lists available at ScienceDirect

Engineering Science and Technology, an International Journal

journal homepage: http://www.elsevier.com/locate/jestch

Full Length Article

Mechanical strength development of mortars containing volcanic scoria-based binders with different fineness

Aref M. al-Swaidani [a,*], Samira D. Aliyan [b], Nazeer Adarnaly [c]

[a] Faculty of Architectural Engineering, Arab International University (AIU), Damascus, Syria
[b] Syrian Arab Organization for Standardization and Metrology (SASMO), Damascus, Syria
[c] The General Organization for Cement & Building Materials (GOCBM), Damascus, Syria

ARTICLE INFO

Article history:
Received 8 October 2015
Received in revised form
23 November 2015
Accepted 19 December 2015
Available online 1 February 2016

Keywords:
Mechanical properties
Fineness
Blended cement
Natural pozzolan
Volcanic scoria

ABSTRACT

The benefits of using natural pozzolan as cement replacement are often associated with shortcomings such as the need to moist-curing for longer time and a reduction of strength at early ages. The objective of the study is to investigate the influence of binder fineness on the mechanical strength development of scoria-based binder mortars. In the study, mortar specimens have been produced with four types of binder: one plain Portland cement (control) and three scoria-based binders with three replacement levels: 25%, 30% and 35%, respectively. All scoria-based binders have been inter-ground into four different Blaine fineness: 2400, 3200, 4200 and 5100 cm^2/g. The development of the compressive and flexural tensile strength of all mortar specimens with curing time has been investigated. The effects of the Blaine fineness of the scoria-based blended cement on the compressive and flexural strengths of mortar have been evaluated at curing ages of 2, 7, 28 and 90 days, respectively. Particle size distribution measured by a laser diffractometer has been considered in the study. Test results revealed that there is a decrease in strength with increasing amounts of scoria. In addition, there was found an increase in strength with increasing the Blaine fineness values. No direct relationship between Blaine and particle size distribution was observed. Effects of Blaine fineness on some physical properties of blended cements such as water demand, setting times and soundness have also been investigated. Further, an estimation equation for strength development incorporating the effects of fineness measured either by Blaine or by particle size distribution has been derived by the authors.

1. Introduction

The term pozzolan, originally applied to a kind of volcanic tuff found at Pozzuoli, is now used generically to define materials which, while not cementitious per se, have constituents that at ambient temperature combine with lime in the presence of water to form compounds that behave like hydraulic binders [1]. Pozzolans have been in use since antiquity. Roy and Langton (1989) [2] suggested that calcined clays mix with slaked lime were the first hydraulic binder to be made. Malinowsky (1991) [3] reported ancient constructions from 7000_{BC} in the Galilee area using this type of binder. The eruption of Thera in 1500_{BC}, which destroyed part of Santorin Island, was responsible for the appearance of large amounts of ashes used by the Greeks to make mortars that reveal having hydraulic properties. However, the Roman already knew that calcined clay was needed to produce mortars with a high performance [1]. According to [4], the Roman mortars used for the Hadrian's Wall in Britain were made of crushed ceramic material mixed with lime binder.

Nowadays, natural pozzolan is being widely used as cement replacement due to its ecological, economical and performance-related advantageous properties [5–10]. However, its use causes longer setting times and lower early strengths compared with plain Portland cement [11].

Strength of concrete is commonly considered its most valuable property. It is well-known that an increase in specific surface area of cement causes an increase in mechanical properties of mortars and concretes, especially at early ages. Since hydration starts at the surface of the cement particles, it is the total surface area of cement that represents the material available for early hydration. Thus, the rate of hydration depends on the fineness of cement particles [12].

To overcome the disadvantages of low early strengths of binders containing natural pozzolans, the prolonged grinding of scoria-based binders could be therefore a solution. Bouzoubaa et al. (1997) [13] reported that increasing the pozzolan fineness increased its strength activity; however, it increased the water requirements. Day and Shi (1994) [14], by studying the effect of grinding on the strength

* Corresponding author. Tel.: +963-11-6119341-7, fax: +963-11-6119340.
E-mail address: aydlswaidani@yahoo.fr; a-swaidani@aiu.edu.sy (A.M. al-Swaidani).
Peer review under responsibility of Karabuk University.

http://dx.doi.org/10.1016/j.jestch.2015.12.006
2215-0986/

development of natural pozzolan from Central America, concluded that a good linear relationship existed. They showed that an increase of 1.5 MPa can be expected for every 1000 cm^2/g increase in fineness. Their study included Blaine fineness in the range of 2500 to 5500 cm^2/g. On the contrary, Rossi and Forchielli (1976) [15] in an earlier study did not find any proportionality between the surface area of pozzolans and reactivity with lime for a given material.

Syria has important volcanic areas. More than 30 000 km^2 of the country is covered by Tertiary and Quaternary-age volcanic rocks [16], among which volcanic scoria occupies important volume with estimated reserves of about three-quarter billion tons [17]. However, their potential use in making concrete is not well established.

The cement produced in the country is almost of CEM I, although an addition of natural pozzolan up to 5% was frequently used in most local cement plants. Hence, less than 300 000 tons of these pozzolans are only exploited annually (the annual production of Portland cement in Syria is about 6 million tons) [18].

This study is part of the first detailed research in Syria to investigate the potential utilization of volcanic scoria as cement replacement in producing Portland-pozzolan cements. In the study, in order to better understand the influence of fineness on the mechanical strength development of volcanic scoria-based binder mortars, compressive and flexural strengths have experimentally been investigated using four Blaine fineness values of 2400, 3200, 4200 and 5100 cm^2/g, respectively. The particle size distribution of the studied binders was also considered in the study. As no significant change in w/b ratio (b: cement + scoria) was observed, its effect on the mechanical strength of mortars could be considered marginal. Some physical properties of the studied scoria-based binder pastes, such as water demand, setting times and soundness have been reported as well.

The study is of particular importance not only for the country but also for other countries of similar geology, e.g. Harrat Al-Shaam, a volcanic field covering a total area of some 45 000 km^2, third of which is located in Syria. The rest covers parts from Jordan and Saudi Arabia.

2. Materials and methods

2.1. Scoria

The volcanic scoria used in the experiments was quarried from Dirat-at-Tulul site, at about 70 km southeast of Damascus as shown in Fig. 1. The mineralogical analysis showed the volcanic scoria is mainly composed of amorphous glassy ground mass, vesicles, plagioclase and olivine with the following percentages (based on an optical estimate): 20%, 35%, 20% and 25%, respectively. Thin sections of the investigated volcanic scoria are shown in Fig. 2. The chemical analysis of volcanic scoria used in the study is summarized in Table 1.

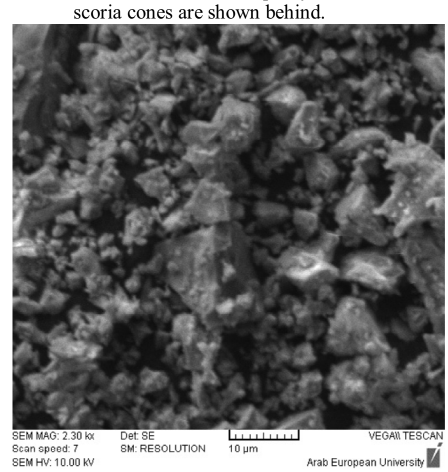
2.2. Binder samples

Four binder samples have been prepared; one plain Portland cement CEM I (control) and three CEM II/B-P samples with three

a. Map of the volcanic area "Harrat Al-Shaam" and the studied site

b. The studied scoria quarry, some volcanic scoria cones are shown behind.

c. Photo of volcanic scoria aggregates as received



d. SEM of ground volcanic scoria

Fig. 1. Map of Harrat Al-Shaam, photos of the studied site, the used volcanic scoria aggregates and SEM of the ground volcanic scoria.