Case Studies in Construction Materials 7 (2017) 191–206

Contents lists available at ScienceDirect

Case Studies in Construction Materials

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

Case study

An investigation on the use of coarse volcanic scoria as sand in Portland cement mortar

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ARTICLE INFO

Keywords:
Physical properties
Mechanical strength
Durability
Mortar
Volcanic scoria
Cameroon

ABSTRACT

In this study, the utilization of coarse volcanic scoria CVS as sand in Portland cement mortar was investigated. The aim of this study is to give some physical properties, mechanical properties and durability properties of CVS mortars investigated at short term of curing in comparison with a reference mortar. Investigation was carried out on three groups of mortar samples according to the proportion of fine particles on the coarse volcanic scoria, "low" for the first group MCVS1, "average" for the second group MCVS2 and "high" for the third group MCVS3. The reference mortar has been made with standard sand. The water–cement w/c ratio and sand/cement s/c ratio used in the mixtures were 0.5 and 3, respectively according to European Standard EN 196-1-2005. The particle size of CVS aggregates used to prepare mortar mixtures were between 0.08 mm and 2.00 mm like in the standard sand. Compressive and flexural strengths were tested at mortar age of 28 days. The results revealed improved compressive and flexural strengths, which were maximal for the MCVS3 samples. Unit weight increased with the ratio of fine CVS size between 0.08–1.00 mm. Sorptivity and carbonation depth decrease as the ratio of fine CVS increase. Based on these results, using Cameroonian volcanic scoria in the appropriate particles size ratio composition will improve these mortar characteristics. CVS mortars can be used for more applications for building construction in Cameroon and all over the world, especially in regions where volcanic scoria resources are abundant.

1. Introduction

The use of some wastes or by-products finely ground in mortar and concrete has become increasingly effective because their use can give better results and be successful, especially from the viewpoint of the mechanical properties or durability of material. In the literature, several waste types have been cited such as volcanic ash, volcanic scoria or tuff, natural pozzolan or ground granulated blast furnace slag as addition or aggregate in mortar [1–13].

Mortar is a workable paste typically made from a mixture of fine aggregate, a binder such as cement or lime, and water. Mortar becomes hard when it sets, resulting in a rigid aggregate structure. It is used in masonry to bind bricks and stones, to provide an even bed between joints, and to plaster and point exposed masonry surfaces. Mortar in a thin liquid form (grout) is used to fill empty joints in masonry, to stabilize soil, to solidify porous rock, to make cast-in-situ reinforced concrete membranes, and has many other uses [14,3].

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http://dx.doi.org/10.1016/j.cscm.2017.07.005
Received 24 March 2017; Received in revised form 5 July 2017; Accepted 30 July 2017
Available online 04 August 2017
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Natural river and sea sand is mostly using in mortar production. The actual requirements of sustainability in construction promote the use of materials which cause a lower environmental impact than those traditionally used. Natural sand mining from rivers and seashores is causing serious environmental problems in many parts of the world, whereas the fine fraction from volcanic scoria deposit is underutilized as a construction material [1]. Aggregates such as coarse volcanic scoria (CVS) aggregates are used in mortars to replace or combine with cement. By using these aggregates, such diverse properties as weight reduction, thermal insulation and fire resistance or workability may be improved. Thus, many lightweight materials such as expanded perlite, expanded glass, hollow microspheres and expanded polystyrene are used without replacing cement, to improve these characteristics [15,3]. The manufacturing of mortars which replace natural aggregates for those of CVS aggregates obtained by crushing of volcanic scoria is a sustainable alternative. An alternative which can only be considered as beneficial as it reduces the exploitation of the existing sea sand quarries, thus conserving natural resources as well as reducing transport costs and minimizing the environmental impact.

Volcanic scoria deposits are abundant in Cameroon. Cameroon has been affected by a gigantic tectonic accident linking the Sao Tome and would continue until the Tibesti. This accident is observed by the alignment of forty massifs over a distance of more than 500 km, from the Atlantic Ocean to Lake Chad which is called the “Cameroon Volcanic Line”(CVL). The CVL is a suite of volcanic and sub volcanic devices, that are aligned in the direction North 30° East. 1600 km long, it is dotted with volcanic massifs of the Southwest to Northeast. It comprises Gulf of Guinea islands, mostly volcanic: Bioko Pagalu, Sao Tome, Principe and also some seamounts; the region of West Cameroon, with alternating mountains: Mount Cameroon (Altitude: 4100 m), the Manengouba Mountains (shield volcano of 20 km in diameter, with no known historic activity presents some Strombolian cones Bamboutou, Mbam and Oku and grabens (Kumba, Tombel, Mamfe, Mbos, Ndop) and end the Tikar lowland (Foumban in Banyo) (Fig. 1). These massifs located in the western part of the country at the border with Nigeria are dotted with their shallow by many scoria deposits. Especially on the slopes of Mount Cameroon, the slopes of Mount Manengouba, Mount Galim, the plains of Tombel around Djoungo, Kumba plain, the plain of Noun around Foumbot, Lake Nyos area and the plateau of the Adamaroua [18].

The advantages of volcanic scoria and tuff include its highly porous structure, high surface area, and low density. It is available in different types, sizes, and colors, and can reduce mortar or concrete dead weight. Similar to other pozzolanic material, such as silica fumes and fly ash, substitution with zeolite can improve the strength of concrete via the pozzolanic reaction with $Ca(OH)_2$ [3,15,19]. It can prevent the bleeding, segregation, and delamination of fresh concrete, facilitate pumping processes, decrease the permeability of hardened concrete, enhance durability (especially resistance to alkali-aggregate reactions), increase concrete strength, and minimize the cracking in concrete caused by self-shrinkage [3,20]. Many authors have investigated the properties of volcanic scoria or tuff sand and checked its suitability for use in mortar mixes [10–13]. Their results indicated that volcanic scoria and tuff sand increased mortar adhesion, bonding strength, and durability. Therefore, this study aims to investigate characteristics of cement mortar using coarse volcanic scoria aggregates in comparison of mortar with standard sand, with a constant water to cement ratio.

2. Experimental program

2.1. Materials

The main components of the mortars investigated are:

– Cement CEM I 52.5 N;
– Clean water from city of Liège (Belgium);
– CEN Standard sand, consisting of siliceous rounded particles or CVS aggregates from volcanic scoria.

The physical and chemical properties of CVS aggregates used in the present work are highlighted below. The choice of local “Djoungo” Cameroonian volcanic scoria materials was based on their abundant availability and accessibility. The cement used was a local ordinary Portland cement type (CEM I 52.5 N), manufactured by the Heidelberg CBR Cement Company located in Lixhe, Belgium. The cement factory conforms to the European Standard EN 197-1 [21]. Its main mineralogical, chemical and physical features are summarized in Table 1 (data made available by the producer company) [22].

Clean water from the urban tap supply of the city of Liège (Belgium) was used: it doesn't contain any element that might negatively affect the quality of the hydraulic mixes. A standard sand conform to European Standard EN 196-1 [23] and packaged in polyethylene bags of (1350 ± 5) g content was used. Its physical proprieties were as follows: relative specific density, (2650 ± 5) kg/m^3; water absorption, 1.5 ± 1%; bulk density, (1530 ± 5) kg/m^3 and maximum grain size, 2.00 mm. Volcanic scoria collected in the main “Djoungo” deposits in Tombel (Fig. 2) were used.

2.2. Methods

In this part, different methods using to characterize volcanic scoria to produce CVS aggregates (chemical and mineralogy composition, mechanical process to obtain CVS aggregates) and different mortars obtained (Physical, mechanical properties and durability) have been presented.

2.2.1. Chemical and mineralogical characterization of volcanic scoria

Chemical and mineralogical characterizations were performed analysis by X-ray fluorescence (XRF) and X-ray diffraction (XRD) methods. The result of chemical composition was compare by several results provide by other authors on the same volcanic scoria

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