Construction and Building Materials 164 (2018) 297–307

Contents lists available at ScienceDirect

Construction and Building Materials

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

Comparing the pozzolanic activity properties of obsidian to those of fly ash and blast furnace slag

İlker Ustabaş [a,*], Ayberk Kaya [b]

[a] Recep Tayyip Erdogan University, Faculty of Engineering, Department of Civil Engineering, 53100 Rize, Turkey
[b] Recep Tayyip Erdogan University, Faculty of Engineering, Department of Geological Engineering, 53100 Rize, Turkey

HIGHLIGHTS

- The Ikizdere obsidians were investigated as a pozzolana in cement.
- The obsidians were compared to fly ash and blast furnace slag.
- The chemical and physico-mechanical properties of the obsidian, fly ash and blast furnace slag added cement were determined.
- It was concluded that the Ikizdere obsidians can be standardized as a pozzolana.

ARTICLE INFO

Article history:
Received 7 July 2017
Received in revised form 20 November 2017
Accepted 27 December 2017

Keywords:
Obsidian
Fly ash
Blast furnace slag
Blended cement
Pozzolanic activity

ABSTRACT

The use of pozzolan in cement provides economic advantages and improves the physico-mechanical properties of cement. Fly ash and blast furnace slag are widely used in cement as pozzolanic materials. In this study, obsidian known as volcanic glass which crops out in the Ikizdere (Rize) region of NE Turkey was investigated as a pozzolana in cement. Mainly the pozzolanic activity, chemical and physico-mechanical properties of the obsidian cement were compared to the properties of the fly ash and blast furnace slag cement. According to laboratory test results, obsidian was seen to provide more positive effects compared to the properties of fly ash cement. It was concluded that obsidian was equivalent to blast furnace slag as a pozzolan. As a result, the obsidian located in the Ikizdere region could be used as a pozzolana in cement.

1. Introduction

The amount of CO_2 released during the production of clinker, constitute 5% and 8% of the amount of CO_2 emitted into the atmosphere by human [1–3]. Using supplementary cementitious materials (SCM) in blended cement production reduces the release of CO_2 into the atmosphere [3]. In addition, substances called pozzolan affect many aspects of cement such as the compressive strength, permeability and chemical durability [4]. Cement sector gives close attention. Several researches are done on pozzolanic matters in nature [5–9].

Pozzolans do not have a binding property on their own but they gain this property when they are used with lime. The most common SCM is natural pozzolans, generally derived from volcanic origins and artificial pozzolans, which are mainly industrial by products/wastes, such as fly ash, different type of metallurgical slags and silica fume. Blending portland cement with pozzolanic admixtures is an effective way to improve workability, strength and durability (lower permeability, resistance to chlorides and sulphates, mitigation of alkali silica reaction) [10–12]. Pozzolans are also among the most common substances used to reduce the hydration temperature of cement [13–15]. An additional benefit of the above approach is that many pozzolanic materials used for blending today would be otherwise stockpiled or disposed in landfills, presenting environmental hazards such as dust contamination or leaching of heavy metals in groundwater. As a result, this reuse and recycling approach in blended cement production contribute to the solution of major environmental problems [16].

Blast furnace slag is a residual product obtaining pig iron. If cooled rapidly, it will have an amorphous structure and when grinded it will show excellent binding properties with the portland cement [17].

Fly ash (FA), which has fine grain property, is another substance with good pozzolanic features [18]. Fly ash and blast furnace slag are among commonly used pozzolans used in the cement. FA is a

* Corresponding author.
E-mail address: ilker.ustabas@erdogan.edu.tr (İ. Ustabaş).

https://doi.org/10.1016/j.conbuildmat.2017.12.185
0950-0618/

waste material generated by the coal combustion in thermal power plants. Fly ash can be used in cement directly or after passing through different processes such as activation as well. Binders obtained by alkali activation of FA (geopolymers) in general are known of having good strength, good durability in aggressive environments, low shrinkage and good thermal resistivity [6,19–21]. However, the limiting factor for wider use of FA for geopolymer synthesis is low reactivity and consequent low reaction rate and low strength gain when cured at room temperature [6,22].

Obsidian is a volcanic rock which is mostly black, to a lesser extent in gray, brown, red and green in hue, glassy bright, fracture surfaces in the form of shells. Obsidian, which is also called volcanic glass because of its amorphous structure, contains very small amounts of crystalline phases and there is very little amount of water (less than 1%) in these crystalline phases. Obsidian formation from molten magma is controlled by chemical composition of the lava and cooling rate [23].

There is a lot of information in the literature on the effects of fly ash and blast furnace slag on properties such as compressive strength, pozzolanic properties, initial-final setting time, and hydration heat of cement. However, there is not enough literature information on using obsidian as pozzolana in cement. In this study, obsidian was compared to fly ash and blast furnace slag on mechanical, chemical and mainly pozzolanic activity properties. The feasibility of the obsidians as pozzolana in cement was investigated with regard to the positive aspects.

2. Material and method

2.1. Materials used in the study

The obsidians used in this study were collected from the Ikizdere (Rize) region, blast furnace slag was obtained from Karabuk Iron and Steel Works, and fly ash was provided from Tuncbilek Thermal Plant located in Turkey. The sampling locations of the materials are shown in Fig. 1.

Pozzolan cement was produced by adding obsidian, fly ash, and blast furnace slag to CEM I 42,5 R class portland cement. Furthermore, the obsidians used in the study were divided into two groups as black obsidian and red obsidian considering their color. Table 1 shows the chemical composition of the materials based on the X-ray fluorescence (XRF) analyses used in this study. The chemical analyses were performed in ACME laboratories, Bureau Veritas Commodities, Canada.

XRD measurements were taken to determine the structural properties and crystal structures of the materials studied in this study. The XRD analyses of cement, obsidian, fly ash and blast furnace slag used in this study are shown in Fig. 2. In Fig. 2a, XRD analysis of cement showed more Alite (C3S) than other phases. The XRD pattern is in a crystallized form which is suitable for a typical portland cement. In the impurity phase, traces of the crystals of the alkalis, sulphates and other compounds mentioned in Table 1 are observed. It is understood that the XRD pattern of Fig. 2b is a material of typical amorphous structure. Besides, silica, alumina and sodium oxide are the most prominent minerals buried in the obsidian amorphous matrix. In Fig. 2c, the quartz peak in the fly ash is the most prominent main phase and the impurity phases are mullite, magnetite, hematite and magnesium ferrite phases. In Fig. 2d, the XRD analysis of blast furnace slag shows that the most prominent peaks are silica, magnesium oxide and aluminium oxide. The XRD analyses of oxide and compounds were found suitable for the chemical composition given in Table 1. Through XRD, obsidian was found to be a substance with an amorphous structure that could be used as puzzolan in cement same as fly ash and blast furnace slag.

The illustrative detailed information about the materials is given in the following chapters.

2.2. Fineness of the materials

In Table 2, Sieve fineness and Blaine fineness values of binders used in the study are shown. According to TS 25 [24] standard, Blaine fineness of natural pozzolan has to be at least 4000 cm^2/g ±%25, at 200 μm sieve remaining by mass % 0.6 at most and at 90 μm sieve remaining % 8 at most. Obsidians used in the study were produced in three different fineness considering the TS 25 [24] standard fineness values by grinding in ball mill for 45, 60 and 75 min. In Table 2, Obsidian45, Obsidian60 and Obsidian75 indicate obsidians with different fineness which were named according to their milling time.

Size distribution of Obsidian45, Obsidian60, Obsidian75, cement, fly ash and blast furnace slag used in this study, which are obtained by laser diffraction particle size distribution, are shown in Fig. 3.

2.3. Thermogravimetric analysis

Thermogravimetric analyses were applied to cement, obsidian, fly ash and blast furnace slag. All the well-defined stages were selected for a study of the decomposition kinetics of the complexes. The kinetics parameters were calculated using the equation of Coats-Redfern [25] given in Eq. (1) to elucidate the kinetic parameters for each stage [26,27].

$$\log\left[\frac{\Phi}{T^2}\right] = \log\frac{AR}{\phi E}\left[1-\frac{2RT}{E_a}\right] - \frac{E_a}{2.303RT} \quad (1)$$

where Φ = [(Wf)/(Wf − Wt)], Wf is the mass loss upon the completion of the reaction, and Wt is the mass loss up to temperature T. A plot of Φ versus 1/T gives a straight line with a slope equivalent to Ea/R.

2.4. Pozzolanic activity and determination of pozzolanic activity index

Hydraulic feature determined through mortar prepared by mixing grinded natural pozzolan, water, slaked lime [$Ca(OH)_2$] and sand in terms of compressive strength is called pozzolanic activity [24]. Pozzolanic activity of pozzolans used in

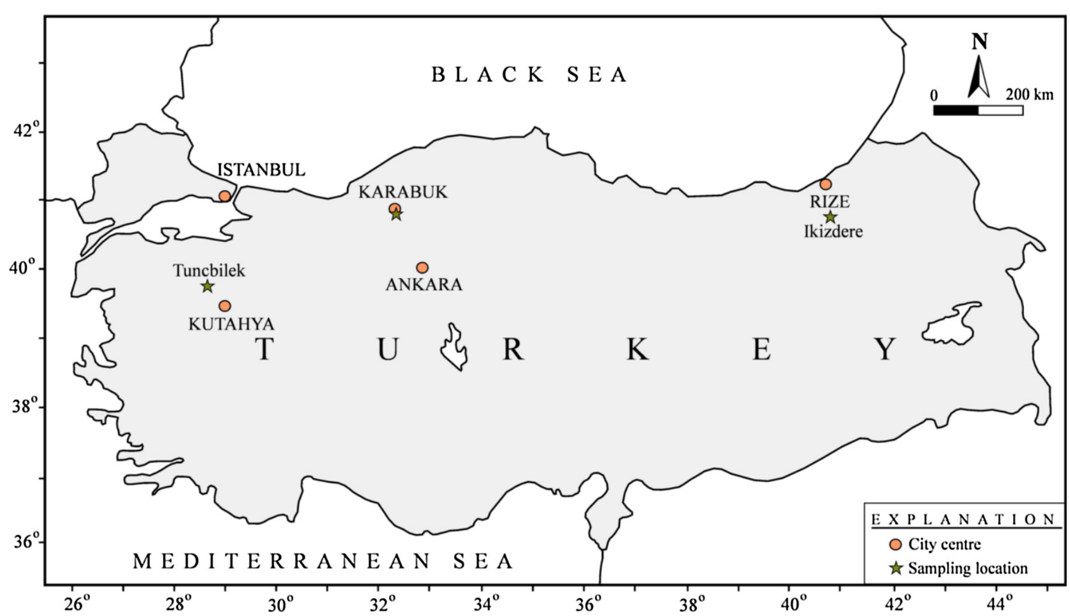

Fig. 1. Location map of the study areas.