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Characteristics of acid resisting bricks made from quarry residues and waste steel slag

Medhat S. El-Mahllawy *

Raw Building Materials Technology and Processing Research Institute, Housing and Building National Research Center, 87 El-Tahreer Street, Dokki, Giza, P.O. Box 1770, Cairo, Egypt

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Abstract

The present work focuses on the recycling feasibility of kaolin fine quarry residue (KFQR) combined with granulated blast-furnace slag (GBFS) and granite–basalt fine quarry residue (GBFQR) to make a brick resistible to chemical actions, particularly sewage waters, and possesses better properties than the conventional one. The conventional brick is composed of clay, feldspar (precious material) and sand with different percentages. Chemical and mineralogical analyses were carried out using X-ray fluorescence (XRF) and X-ray diffraction (XRD) techniques, respectively. Also, scanning electron microscopy (SEM) as well as energy dispersive X-ray (EDX) analyses was used to study the microstructures of some selected fired specimens. Solid briquettes were made from five suggested batches. These batches contained 50% of KFQR as a constant percentage, while the percentage of GBFS was increased from 10 to 40% on the expense of GBFQR percentage which was decreased from 40 to 10% (by weight). Firing was performed from 1100 °C to 1175 °C at an interval of 25 °C with 5 °C/m (firing rate) and 4 h as the soaking time. In order to evaluate the possibility of making acid resisting brick (ARB), the fired specimens were characterized with respect to the Egyptian standard specification (ESS 41-1986) as well as bulk density, volume changes and firing weight loss. The study shows that the batch S2 containing 50% KFQR, 20% GBFQR and 30% GBFS fired at 1125 °C exhibits the most satisfying ceramic properties that meet the ESS requirements for making acid resistant brick. The study also indicates that the addition of more than 25% of GBFQR is not recommended, as it is significantly deleterious to the ceramic properties.
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Keywords: Kaolin fine quarry residue; Granulated blast-furnace slag; Granite–basalt fine quarry residue; Acid resisting brick; Processing; Sintering

1. Introduction

It is well known that the disposing of industrial wastes is one of the major worldwide environmental problems. In Egypt, for example, there are a limited number of dumping landfill sites and generally the disposal methods are considered to be environmentally unfriendly. Furthermore, as a consequence of environmental and financial considerations, there is a growing demand for wastes to be re-used or recycled. At present, the utilization of blast-furnace slags, basalt–granite and kaolin fine quarry residues is an urgent environmental and ecological demand, especially after the increase of the annual accumulation of these pollutants.

Blast furnace slag is a nonmetallic by-product from iron and steel industry. It is generated during the conversion of iron ore or scarp iron to steel, along with coke for fuel. Production of one tonne of steel leads to the manufacturing of 500–700 kg of slags [1]. The molten slag comprises about 20% by mass of iron production. Some steel slags may contain hazardous elements such as Pb, Cd, Ni and Cr [2]. Different forms of slag products are produced depending on the method used to cool the molten slag. These products include air-cooled blast furnace slag, expanded or foamed slag, palletized slag, and granulated blast furnace slag. In this study granulated blast furnace slag is considered, which is cooled and solidified by rapid water quenching

* Tel.: +20 2 0103031173; fax: +20 2 2335151564.
E-mail address: m.sobhy@hbrc.edu.eg.

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to a glassy state with little or no crystallization. Many solutions have been proposed for the technical treatment of the blast furnace slag in variable fields and industries such as concrete works [3], steel corrosion prevention [4], reduction of alkali silica reactivity [5], cement industry [6], road constructions [7], clay brick production [8] and ceramic field [9].

On the other hand, the quarrying of crushed kaolin and basalt–granite aggregates generates a considerable volume of quarry fines, often termed 'quarry dust' and 'filler grade'. The fine fraction of aggregate products (the quarry dust) is usually smaller than 5 mm in size. When the quarry fines consist of a grade mix of coarse, medium and fine sand sized particles, plus a clay/silt fraction of less than 0.075 mm, they can be described as the 'filler grade' residue [10]. The investigated residues have been used before in many useful applications, such as fertilizer for acid soils [11], production of ceramic bricks and tiles [12,13] and making of building clay bricks [14].

The present study focuses on the recycling feasibility of kaolin fine quarry residue (KFQR) combined with granulated blast furnace slag (GBFS) and basalt–granite fine quarry residue (GBFQR) to make acid resisting brick, at relatively low cost, and with good physical, chemical and mechanical properties. Furthermore, this study will maximize the industrial profitability and abate both wastes and environmental impacts.

2. Materials, methods and processes

2.1. Materials

In this study, two fine quarry residues and one industrial waste were used. The kaolin fine quarry residue (KFQR) was acquired from Abu-Zenima crusher (South Sinai, Egypt). Granite–basalt fine quarry residue (GBFQR) was collected from a crusher site near Hurghada (Egypt), while the granulated blast furnace slag (GBFS) was taken from the stock piles of the Egyptian Iron and Steel Co. which is located in Abu-Za'bal area (Egypt).

2.2. Methods and techniques

The chemical composition of the studied starting materials was determined via a computerized X-ray fluorescence (Philips, PW 1400 Spectrometer, Holland). The mineralogical composition was obtained by using X-ray diffraction technique (Philips, PW 1730 Vertical Diffractometer, Holland). This analysis was run at 40 kV and 25 mA using Cu Kα radiation. The used 2θ was from 15° until about 50°. The identification of the resultant minerals was achieved by using Traces software Version 6 (Microsoft Co., USA).

The microstructure of some selected fired specimens was investigated through the scanning electron microscopy (Leica Steroscan 440, UK). The fired specimens were dried for 24 h and then coated by carbon using the SPI-Module Carbon Fiber Coater. The magnification power was 2000× with an accelerating voltage of 20 kV.The obtained results were analyzed and normalized using energy dispersive X-ray (EDX) attached unit, which also helped in phase identifications and microstructure observations.

Table 1
Suggested mixtures from the materials used

Batch no.	Composition (% by weight)		
	Kaolin fine quarry residue (KFQR)	Granite–basalt fine quarry residue (GBFQR)	Granulated-blast furnace slag (GBFS)
S1	50	10	40
S2	50	20	30
S3	50	25	25
S4	50	30	20
S5	50	40	10

2.3. Batch preparation and specimen process

In order to investigate the feasibility of manufacturing the acid resisting brick (ARB), five suggested batches, namely S1, S2, S3, S4 and S5, were designed for the current study. These mixtures composed of 50% of KFQR and 10–40% of GBFQR and GBFS, as given in Table 1. These starting materials were crushed, separately ground in a laboratory ball mill, and screened to pass 90 μm sieve.

Every batch was first homogenized in a blender, then molded in 5 cm-side length cube by pressing under 225 kg/cm^2. Mixing the batches components was implemented on a dry basis with spraying 5% water before molding. After forming, the green briquettes were dried out in an electrical dryer at 80 °C for 24 h, and then fired at different firing temperatures (T_f) of 1100 °C, 1125 °C, 1150 °C and 1175 °C at 5 °C/m firing rate and 4 h soaking time in a muffle furnace under oxidizing condition. Finally, the specimens were cooled inside the furnace until room temperature.

In order to assess the physical, chemical and mechanical characteristics of the fired specimens, each batch composition is examined against the requirements of the Egyptian standard specification [15]. In addition, the volumetric changes, firing weight loss and bulk density were calculated. Accordingly, the successful and promising batches were identified and suggested for making acid resisting brick.

3. Results and discussion

3.1. Characteristics of raw material

The chemical composition of the materials used is depicted in Table 2. It is clear that both the KFQR and GBFQR are composed essentially of SiO_2 and CaO. The GBFS is composed mainly of SiO_2, CaO, Al_2O_3 and BaO in descending order of abundance rather that other oxides content. From the chemical composition of the original

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