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Clay-bricks from recycled rock tailings

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ABSTRACT

The aim of this work is to optimize the industrial applications of granite and kaolinite rock tailings in ceramics industry. Three rock tailings are selected to be characterized and equally mixed for testing. The samples are characterized using XRD, XRF, polarizing light microscope, cathodoluminescence, X-ray micro-computed tomography (3D-μCT) and SEM microscopy attached with EDAX. The rock tailings mixed batch is non-bloatable and is located in the mullite field on the FeOFe$_2$O$_3$-Al$_2$O$_3$-SiO$_2$ phase diagram. In addition to primary mullite, type II secondary mullite of aspect ratio (3-10:1) is characteristic within aluminosilicate glassy matrix. The 3D-μCT shows pores of lower surface area at 1200 °C due mainly to the existence of isolated rounded closed pores. The physical characteristics of the fired batch, at 1200 °C show that it can be used in the manufacture of building clay-bricks.

1. Introduction

The increasing worldwide industrial growth implies serious environmental problems. Such industrial growth depends mainly on the natural non-renewable resources which will be depleted sooner or later. Enormous increase in the amounts of wastes/tailings associates the raw material-based industrial activities [1–3]. The recycling of the different industrial tailings has long been considered as ideal way to inertize different hazardous wastes [4]. Such recycling process will preserve resources, lower energy consumption, reduce costs and improve health and safety [1,5,6].

There are different types of ornamental stones such as granites, marbles, slates and many others which are used in building, monuments, architecture and sculpture. The processing of the ornamental stones includes mainly the extraction, sizing and polishing and is associated with large amounts of stone tailings as solids and sludges [7]. The aqueous sludge/slurry is a mixture of fine rock wastes and abrasive metallic shots [2]. The destiny of this sludge is mostly in the landfills or the aqueous environment which could cause environmental impact like the turbidity increase of the water courses [7]. After drying, the granitic sludge tailing adopts a form of fine non-biodegradable dried powder/mud which is easily dragged by the wind and becomes harmful to humans and animals.

The granitic tailing is compositionally very similar to the processed granitoid rocks. Mineralogically, this powder granitic tailing mostly contains feldspars, quartz, micaceous minerals and calcite. Consequently, its chemical composition is enriched in SiO$_2$, Al$_2$O$_3$, K$_2$O, Na$_2$O and CaO associated with low coloring oxides Fe$_2$O$_3$, MnO, TiO$_2$ and Cr$_2$O$_3$ [8]. Thus, the granitic tailing is an attractive additive for traditional building materials [2,9,10].

The granitic tailings could be used in the manufacture of clay-based ceramic bricks and tiles after firing between 750 and 1150 °C. During firing, such tailings are easily incorporated into the microstructure of the clay-based bricks and enhance their properties [4,7,11–13]. The main role of the granitic tailing is to encourage the liquid phase formation, which contributes in the acceleration of sintering at low temperature and consequently led to the formation of bodies with denser microstructure and better technological properties [2,9,14,15].

In Egypt, the main industrial zone for processing the ornamental stones is located in the Greater Cairo and is called Shaq Al-Thoaban. Saving energy and natural resources conservation are demands in the Egyptian society to have a cleaner production/environment and to raise the economic returns. Therefore, the granitic tailing of Shaq Al-Thoaban industrial zone is chosen for

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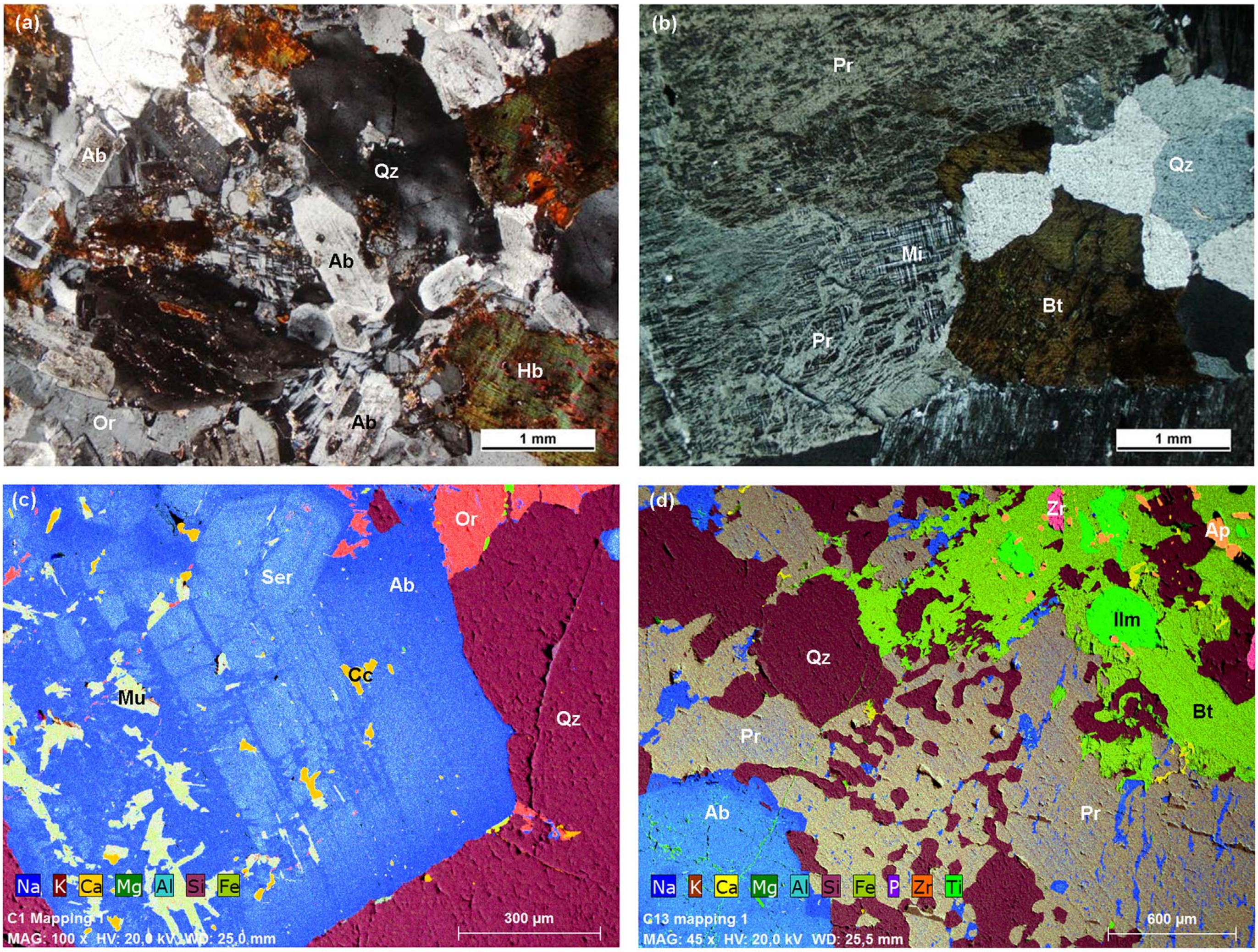

Fig. 1. (a, b) TLM photomicrographs showing the mineralogical composition of the granitic ornamental stones (X-Nicols) (Qz: quartz; Ab: albite; Or: orthoclase; Pr: perthite; Mi: microcline; Hb: hornblende; Bt: biotite). (c, d) BSE elemental maps showing the distribution of different elements in the granitic ornamental stones (Cc: calcite; Mu: muscovite; Ilm: ilmenite; Zr: zircon; Ap: apatite; Ser: sericite).

recycling together with other clay tailings from kaolin quarries that a novel waste-only clay-based brick can be obtained and used as building bricks.

2. Materials and methods

The raw materials used in this work are mainly rock tailings. The ornamental stone granite tailing sample (GT), which acts as inert fluxing component, was collected from Shaq Al-Thoaban industrial zone. In addition, rock cuttings represent the different types of the processed ornamental stones were collected as well. The other two rock tailings, which act as plastic components, are mainly clays collected from Aswan (AT) and Sinai (ST) kaolin quarries tailings.

Representative 500 g of the three rock tailing samples were ground separately in an agate ball mill, sieved to pass a 63 μm sieve and dried overnight at 110 °C. All tailing samples were characterized for their mineral and chemical composition using X-ray diffraction and fluorescence (XRD and XRF) methods, respectively. The powder X-ray diffraction (PXRD) was carried out on a PANalyticalX´Pert Pro X-ray diffractometer with X'Celerator RTMS detector in Bragg-Brentano-geometry (tube settings:45 kV, 40 mA) using Cu-Kα radiation, $\lambda = 1.5418$ Å, within a range of $3° \leq 2\Theta \leq 70°$, with a step size of 0.016° 2Θ and an irradiation time of 19.96 s/step. The phase identification and quantitative Rietveld refinements were done using the software HighScore Plus (PANalytical) and the rutile TiO_2 as internal standard. The Rietveld refinements goodness of fit (GOF) is also determined. The chemical composition of the three tailings and the rock cuttings were determined by semi-quantitative XRF analysis using a Bruker SRS3000 spectrometer working with rhodium radiation (tube settings: 60 kV, 150 mA) and WDX detecting system. The samples were prepared as pressed pellets each of 8 g sample material and 2 g wax. The granulometry of the three rock tailings were determined by laser diffraction using Cilas 1064 L equipment.

A batch composition sample (BC) was prepared by mixing the three rock tailings; (GT); (AT) and (ST) equally (1:1:1) in a cylindrical dry mixer for 30 minutes. The moisture content of the batch was adjusted to 7 wt.%. The latter batch was pressed by uniaxial pressing at 26 MPa into thirty five discs of 15 mm diameter and 5 mm thickness. The green discs were dried for 24 h at 110 °C and then fired at 900, 950, 1000, 1050, 1100, 1150 and 1200 °C – five discs at each – with heating/cooling rate of 5 °C/minute for 15 minutes soaking time. The firing conditions used in this study were chosen to simulate the actual firing process used in the clay-brick industry. The physico-mechanical characteristics of the fired discs, in terms of linear shrinkage; bulk density;