Fuel Processing Technology 130 (2015) 263–267

Contents lists available at ScienceDirect

Fuel Processing Technology

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

Microwave synthesis of thermal insulating foams from coal derived bottom ash

Ehsan Ul Haq, Sanosh Kunjalukkal Padmanabhan *, Antonio Licciulli

Department of Engineering for Innovation, University of Salento, Lecce 73100, Italy

ARTICLE INFO

Article history:
Received 2 July 2014
Received in revised form 6 October 2014
Accepted 13 October 2014
Available online 5 November 2014

Keywords:
Bottom ash
Microwave foaming
Geopolymer
Thermal insulation
Mechanical strength

ABSTRACT

Bottom ash from coal-fired power plants is a potential raw material for the production of ceramic tiles, bricks and blocks for various applications. In this work we are presenting a novel microwave method to utilize the bottom ash to produce thermal insulating bricks. Foam samples were prepared by microwave foaming of the mortar prepared by milling the bottom ash, sodium silicate and NaOH. The microwave foaming ability of different slurry compositions and the physical and mechanical properties of the foamed samples were evaluated. FTIR analysis reveals that the degree of geopolymerization increases with increasing fraction of sodium silicate. Foams with low bulk density, high porosity, low thermal conductivity and compressive strengths were obtained by this method. With varying the bottom ash to sodium silicate ratio, it is possible to modulate the physical and mechanical properties of the insulating bricks.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

Fly ash (FA) and bottom ash (BA) are the two major by-products from coal fuel power stations. Bottom ash is a dark gray, granular, porous, incombustible sand-like material, which is collected in water filled hopper at the bottom of the furnace during the combustion of the coal [1]. Bottom ashes have been viewed as a serious environmental problem [2]. Depending on the coal source, bottom ashes might contain several toxic elements, such as lead (Pb), zinc (Zn), cadmium (Cd) and copper (Cu) [3]. These toxic elements can leach out and contaminate soils as well as surface and ground water [4]. The disposal of bottom ash is a matter of great concern, as the dumped ash is highly unsuitable for the agricultural uses and it makes the agricultural land barren and unproductive [5]. So much research is being conducted from more than two decades for the use of coal ashes in construction such as cement and brick production [6,7]. Many researchers have also studied the use of bottom ashes for the removal of dyes and organic pollutants from waste water [8,9].

Bottom and fly ashes, can be used to produce the so called geopolymers [10]. Foam glass, an interesting material has attracted great interest and has been applied in many areas such as building, chemistry and defense fields because of complex properties including low thermal conductivity, low density, incombustibility, etc. [11]. The combination of bottom ash with water glass (sodium silicate) under controlled foaming procedure gave bulk or highly porous materials with surface or/and bulk crystallization. The foaming process leads to the reduction of energy consumption and ecologically risky components from the waste that are fixed molecularly in the silicate phase and additionally inserted in the ceramic matrix, which either have no toxic inserted components or have them in eco-compatible concentration. The most common method used for creating pores is by adding a suitable amount of porogen and subsequent removal of porogen by heat treatment. Chen et al. have studied the fly ash for the synthesis of foam glass using different foaming agents [12,13]. This method has a disadvantage due to the formation of toxic gases on porogen removal by heat treatment.

Recently microwave energy has been discovered as an innovative tool for heating and chemical reactions due to microwave bulk penetration and microwave absorption selectivity [14,15]. The advantages of microwave heating include instantaneous and fast heat up time and easy control [16,17], where microwave energy is delivered directly to the material through the interactions at the molecular level with the electromagnetic field. Microwaves penetrate the material and provide energy, resulting in volumetric heating. It has been reported that microwave is used as a powerful tool for making polymeric foams [18,19] by improved heat transfer, which is usually limited in polymers due to their low thermal conductivity. Microwave has the ability to penetrate deep inside the material being electromagnetic in nature in a short time and hence the water in the entire body quickly reaches at a higher temperature by volumetric heating, vaporized in a short while, creating foaming in the mass.

The aim of this study is to investigate the possibility of applying microwave heating in the processing of bottom ash-sodium silicate geopolymer foam, which is an attractive candidate for thermal

* Corresponding author. Fax: +39 08321830130.
E-mail addresses: Sanosh.padmanabhan@unisalento.it, Sanosh2001@gmail.com (S. Kunjalukkal Padmanabhan).

http://dx.doi.org/10.1016/j.fuproc.2014.10.017
0378-3820/© 2014 Elsevier B.V. All rights reserved.

Table 1
Compositions of foam samples.

Sample name	Ash (wt.%)	Sodium silicate (wt.%)	14 M NaOH (wt.%)
BA40	40	55	5
BA50	50	45	5
BA60	60	35	5
BA70	70	25	5

Table 2
Composition of bottom ash as determined by XRF analysis.

Species	w/w %
Al_2O_3	21.29
SiO_2	52.68
K_2O	2.41
CaO	5.43
TiO_2	1.36
Cr_2O_3	0.03
Fe_2O_3	16.49
NiO	0.01
CuO	0.03
SrO	0.21
Total	100

insulation. The microwave foaming ability of different slurry compositions and the physical and mechanical properties of the foamed samples were evaluated. The inorganic foams derived from this process have excellent thermophysical properties, are non-flammable, and safe for humans and the environment.

2. Experiment

2.1. Materials

The raw materials used for the synthesis of foamy geopolymers were bottom ash (provided by ENEL, Brindisi), sodium silicate ($Na_2O{\cdot}3SiO_2$) having a density of 1.37 g/cm^3 and 42–46% concentration (Prochin, Italy) and 14 M sodium hydroxide as an activator solution. The surface area and elemental composition of the bottom ash sample were evaluated by BET (Quantachrome) and XRF (Bruker M4 Tornado) respectively. The morphology and particle size of the bottom ash were analyzed by a scanning electron microscope (SEM: Zeiss-EVO) and laser particle size analyzer (Cilas1190).

2.2. Sample preparation

Table 1 shows the composition of the investigated slurries from which all samples were synthetized. The samples were named as BA40, BA50, BA60 and BA70 respectively for 40, 50, 60 and 70 weight percentage bottom ash compositions used. All the ingredients were combined in a polyethylene jar and milled in a horizontal ball mill with alumina balls as grinding media for 24 h to get a homogenized slurry. After milling, a prefixed amount of the slurry was poured into a specially designed teflon mold and then treated in the microwave oven (EM 45 MLS 1200 mega MILESTONE power 900 W) for 4 min to complete the forming process. After forming, the samples were carefully demolded and again treated in the microwave for one more minute to remove the moisture and to make the samples insoluble in water.

2.3. Characterization of foamy material

The crystalline phases formed during microwave foaming were characterized by X ray diffractometer (Rigaku D/max 2550PC). The pore structure and pore morphologies were investigated by a scanning electronic microscopy. The bulk density of samples was calculated as the ratio of mass to volume, and the powder density was measured with helium pycnometer. The total porosity was calculated from the bulk density and powder density using the following equation:

$$\%\,Porosity = (1 - bulk\ \ density/powder\,density) \times 100$$

Mechanical strengths were evaluated by compression tests according to ASTM standards C-365 using a standard testing machine (Lloyd LR5K instrument) equipped with a 5 kN load cell. Five samples from each group were tested to obtain average value of mechanical strength and standard deviation. Fourier Transformation Infrared spectroscopy was performed using ATR spectrometer (Attenuated Total Reflectance; PerkinElmer) with diamond crystal as a probe. The thermal conductivity was measured with a thermal conductivity analyzer (Mathis TCi, SETARAM) utilizing the modified transient plane source technique.

3. Results and discussion

3.1. Composition of bottom ash

From the X-ray Fluorescence analysis, it can be seen that the major components present in the bottom ash were silica (52.68 w/w.%), alumina (21.29 w/w.%) and iron oxide (16.49 w/w.%) with fractions of calcium, potassium, nickel, titanium, copper, strontium and manganese oxides (Table 2). The bottom ash particles are spherical in shape and have a diameter in the micron range as shown in the SEM micrograph (Fig. 1a). The particle size distribution of bottom ash is shown in Fig. 1b. The mean diameter of the particle is 121 μm and diameter at D50 is 81.96 μm. The specific surface area of the bottom ash measured by BET method is 2.42 m^2/g. It is evident that this low surface corresponds to the big particles present in the bottom ash.

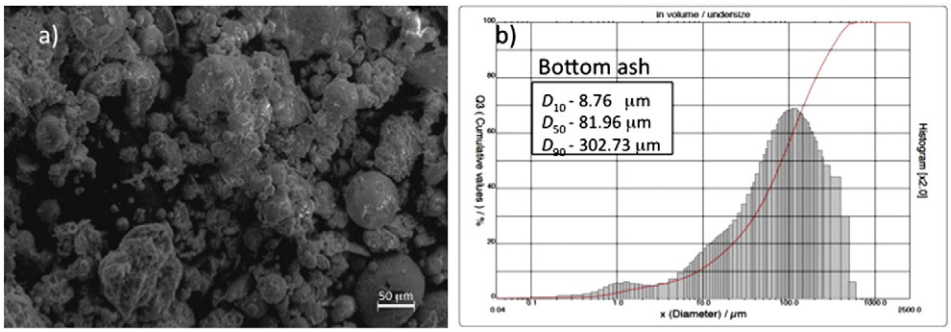

Fig. 1. a) SEM micrograph and b) particle size distribution of bottom ash particles.

Download English Version:

https://daneshyari.com/en/article/209561

Download Persian Version:

https://daneshyari.com/article/209561

Daneshyari.com