Construction and Building Materials 125 (2016) 119–126

Contents lists available at ScienceDirect

Construction and Building Materials

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

Technical note

Influence of the mechanical activation of raw mixes on the properties of foam glass from sand sludge

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HIGHLIGHTS

- Mechanical activation improves the foam glass characteristics from sand and sludge.
- Particle size was determined from sand sludge for optimal foam glass characteristics and structure.
- Mechanical activation accelerates the glass formation process.

ARTICLE INFO

Article history:
Received 4 May 2016
Received in revised form 5 July 2016
Accepted 23 July 2016

Keywords:
Foam glass
Sand sludge
Recycling
Porous materials
Mechanical activation

ABSTRACT

This paper reports the results of mechanical activation influence investigations on foam glass properties from sand sludge. Sand sludge is a waste product from crushing and screening plants for sand and gravel production. The results show the mechanical activation efficiency of the raw mix as a structural regulation tool and the properties of foam glass from sand sludge. Mechanical activation of the raw mix for 20 min to a particle size of 50 μm allows the sample to receive granular foam glass with a bulk density of 200 kg/m^3, a strength of 0.63 MPa and a water absorption of 1.4%.

1. Introduction

The building materials of the future are those that combine excellent insulating qualities as well as constructive usability with recyclability and low global warming potential. Within the extended raw material spectrum exist further questions such as how solid waste or waste muds can be converted in environmentally friendly raw materials by a low energetic production process. In addition, industrial ware materials need to maintain low environmentally hazard loads, as well as use an alternative raw materials source that fulfils current rules and norms.

A promising alternative raw material that has never attracted much interest is sand sludge. According to the Federal Institute for Geosciences and Natural Resources of Germany, approximately 50 million tons per year of sand sludge are accrued in Central Europe, most of which remains unused. Estimations state that less than 0.7% (approximately 100,000 tons per year) is presently fed back into industrial applications; a portion of the sand sludge is used in the brick industry [1]. Sand and gravel are obtained through opencast mining and are processed in processing plants. At the processing plants, the sand and gravel are washed and classified by particle size, and the ultra-fines are separated in suspension. This water solid mixture, the washing sand sludge, is disposed of primarily in nearby retention ponds [2]. The authors of publications [3–6] used sand sludge to produce lightweight aggregates at temperatures of 1100–1300 °C. The results of previous studies [7] showed the possibility of receiving foam glass from sand sludge at temperatures below 1000 °C. The aim of this work is to develop a particle size influence of raw mix from sand sludge on the sintering and foaming process kinetics and the resulting properties of the foam glass.

Mechanical activation is an effective method to enhance the contact and interaction of the reactants by decreasing their particle size and increasing their homogeneity by the milling process. This activation process facilitates the formation of new phases in the subsequent thermal treatment [8].

The first applications of mechanochemistry in the building industry are related to the benefit of silicate concrete (Silicalcite) production [9,10]. The main advantage of this application is in the mechanical activation of quartz, which has a positive influence

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http://dx.doi.org/10.1016/j.conbuildmat.2016.07.116
0950-0618/

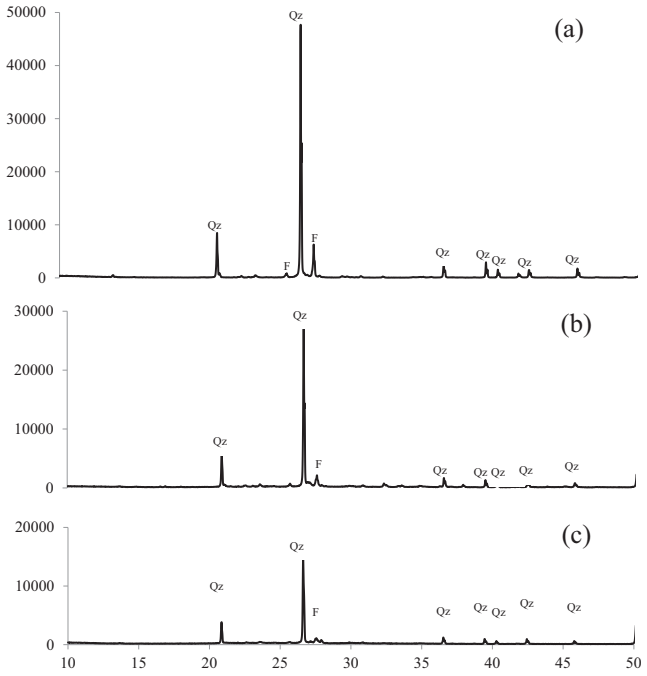

Fig. 1. X-ray diffraction pattern (Cu Ka) for: (a) sand sludge, (b) frit after 850 °C from unmilled raw mix and (c) frit after 850 °C from raw mix milled for 20 min: Qz, Quartz; A, Anorthoclase.

on calcium hydrosilicate (CHS phase) formation [11,12]. The mechanical activation of three natural acidic igneous rocks, including granite, pumice and perlite, were studied in [13]. Previous studies [14–16] demonstrated the influence of fly ash mechanical activation on the mechanical properties and structure of geopolymers.

To date, mechanical activation synthesizes a large number of chemical compounds and some regularities of mechanochemical reactions were determined [17–19]. Differences in the thermal behaviour of natural quartz before and after mechanical grinding were described in [20–25].

The objective of the present investigation was to study the structure and behaviour of foam glass materials from sand sludge, which were mechanically activated in a planetary-type mill for different periods. The effect of mechanical activation on reaction, structure and properties of granular foam glass was elucidated using isothermal conduction calorimetry, X-ray diffractometry (XRD), differential thermal analyses, light microscopy and the evaluation of its physical-mechanical properties. The results of preliminary studies are encouraging, since they confirm the possibility of using this type of raw material for the production of lightweight granulated material, that can be used as a heat insulation filler.

2. Materials and methods

The chemical composition of the sand sludge as determined by X-ray fluorescence analysis (XRF) is shown in Table 1.

Fig. 1a shows the XRD patterns of the sand sludge. The X-ray diffraction (XRD) analyses were conducted on a Bruker D8-Advance based diffractometer. The radiation applied was Cu Kα from a broad focus Cu tube, operating at 40 kV and 40 mA. The samples were measured in step scan mode with steps of 0.02° 2θ and a counting time of 5 s. The main crystalline phase of the mineralogical composition represents a mixture of quartz and feldspar.

The granulometric composition of sand sludge was measured with a laser granulometer Horiba (Retsch) and is shown in Table 2.

To reduce the fusion temperature of the mixture, soda ash was added as a fusion agent. Carbon black type 220 (ASTM D1765) was used as an expanding agent in the production of the granular foam glass. The carbon black was obtained from the thermal-oxidative decomposition of liquid hydrocarbon raw materials and represents highly active carbon with a high dispersity and good structural properties. The specific surface of carbon black is $1.14 \cdot 10^5$ m^2/kg.

Table 2
Granulometric composition of sand sludge.

Specific surface (cm^2/cm^3)	d measurement average (μm)	d_{10} (μm)	d_{50} (μm)	d_{90} (μm)
535.06	314.34	167.26	305.66	482.57

Table 3
Particle size and specific surface area of the raw mix milled for different periods.

Milling time (min)	Specific surface area (cm^2/cm^3)	d measurement average (μm)	d_{10} (μm)	d_{50} (μm)	d_{90} (μm)
0	279.3	366.2	205.3	342.5	581.2
20	4322.6	55.4	5.7	34.2	160.6
40	5656.0	30.9	4.9	12.3	82.2
60	6605.4	24.0	4.2	10.7	58.4

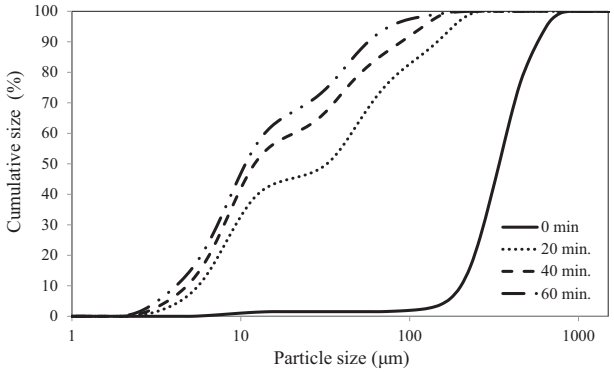

Fig. 2. Particle size distribution of raw mix milled for different time.

3. Results and discussion

3.1. Mechanical activation effect of the raw mix

It is well known that a similar particle size distribution of the raw materials is important and promotes homogeneous

Table 1
Chemical composition of the sand sludge.

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO + MgO	MnO	R_2O	P_2O_5	SO_3	Loss on ignition
Oxide content (wt.%)									
84.0	0.21	8.6	1.23	0.61	0.01	5.2	0.06	<0.01	1.22