

Technical Note

Lightweight aggregates produced from sand sludge and zeolitic rocks

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HIGHLIGHTS

- Zeolitic rock improves the characteristics of lightweight aggregates.
- Introduction of 20% zeolitic rock reduces the temperature required by 50 °C.
- Lightweight aggregates with the addition of zeolitic rocks have a total porosity of 60–70%.

ARTICLE INFO

Article history:

Received 20 October 2014

Received in revised form 23 February 2015

Accepted 4 March 2015

Available online 30 March 2015

Keywords:

Lightweight aggregates

Building materials

Processing

Raw materials

Porous materials

ABSTRACT

This paper reports the results of investigations on manufacturing lightweight aggregates from sand sludge with zeolitic rocks added to decrease the foaming temperature. Sand sludge is a waste product from crushing and screening plants for sand and gravel production. Introduction of 20% zeolitic rock into the raw mix composition reduces the temperature required to produce lightweight aggregates by 50 °C and improves their physical–mechanical characteristics. Lightweight aggregates using sand sludge with zeolitic rocks added have porous structures, with a total porosity of 60–70%; this material is recommended for use as lightweight aggregates for concrete and as heat-insulating filling.

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1. Introduction

The main features of lightweight aggregates are their high porosity and resulting low density. Natural and manufactured lightweight aggregates are available. Natural lightweight aggregates include diatomite, pumice, volcanic slag, volcanic ash and tuff. Except for diatomite, all of these rocks are of a volcanic origin. Natural lightweight aggregates have found limited use because they are available only in select areas of the globe. Manufactured lightweight aggregates are known under various trade names and are produced from different raw materials. The most frequently used lightweight aggregates are made from clay, shale, perlite, vermiculite and different types of sintered waste.

Previous investigations proposed the production of lightweight aggregates for concrete with different types of wastes. These studies [1–2] suggest using building wastes in the production of aggregates for concrete. Additionally, the results of studies in which

concrete aggregates were obtained from ash waste were previously presented [3–7].

Previous studies [8–15] also considered the use of sewage sludge in the production of lightweight aggregates. Investigations [16–25] report having elaborated a technology that allows the production of a porous material from zeolite containing minerals.

A promising alternative raw material that has attracted minimal previous 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 [26]. 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 [27]. Previous publications [28–31] used sand sludge to produce lightweight aggregates at temperatures of 1100–1300 °C.

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The results of the studies presented in [32] then showed the possibility of receiving lightweight aggregates from sand sludge at temperatures below 1000 °C.

The objective of the present studies was to even further reduce the energy consumption in this context the effect of zeolitic rock as an additive was explored and it was found that the foaming temperature can be decreased to values below 950 °C. Additionally, the properties of the materials produced were characterised.

2. Raw materials

The mineralogical composition of sand sludge represents a mixture of quartz, feldspar, different clay minerals, carbonates and oxides; an overview of the chemical composition is shown in Table 1. The granulometric composition of sand sludge covers a particle size range of 2–63 µm.

Zeolites are tectosilicates, characterised by wide-meshed invested structures with large hollow cavities or canals containing large cations, such as Na⁺, Ca²⁺, K⁺, Ba²⁺ and Sr²⁺, and notably H₂O molecules, called zeolite water. Loose bonds render the cations easily interchangeable. The zeolite water can be gradually driven out by moderate heating without breaking down the aluminosilicate frame [33].

The investigations described hereafter used zeolitic rock originating from the Carpathian region. Apart from the zeolite target material (heulandite), the mineral composition is comprised of silica, plagioclases and clay minerals. The zeolite weight fraction is in the range of 77%. Fig. 1 shows the XRD patterns of the zeolitic rock. 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 lightweight aggregate. This carbon black is 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 · 10⁵ m²/kg.

3. Results and discussion

3.1. Composition of raw materials

Three compositions of raw mix were selected for study, in which the content of sand sludge was gradually increased, while that of zeolitic rock was gradually decreased by the same percentage:

- (1) sand sludge 40%, zeolitic rock 40%, and soda 20%;
- (2) sand sludge 50%, zeolitic rock 30%, and soda 20%;
- (3) sand sludge 60%, zeolitic rock 20%, and soda 20%.

For the preparation of the raw material mix, all components were ground in a ball mill. Fig. 2a shows the XRD patterns of the raw mix. The mineralogical composition of the raw mix represents a mixture of zeolite minerals, quartz, and feldspar. To better understand the thermal processes occurring during the preliminary firing of the raw material mixture, Differential Thermal Analyses were performed using a TA-Instruments Netzsch STA 429 thermo-gravimetric analyser (Fig. 3). The endothermic effect at 98.4 °C (DTA) corresponds to the release of adsorbed water. The subsequent weight loss of 10.92% over the temperature interval from 400 to 800 °C can be attributed to the release of water from the zeolite, the dehydroxylation of the clay minerals and the decarbonation of calcium carbonate. If the temperature is further increased, then chemical reactions initiate in the temperature interval of 720–850 °C, characterised by the formation and melting

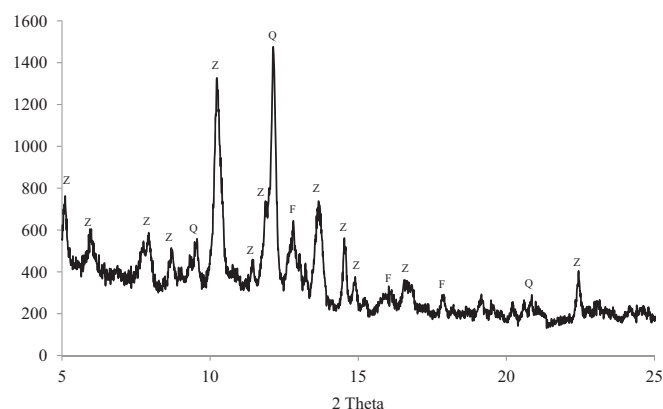
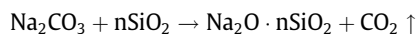


Fig. 1. X-ray diffraction pattern (CuK_α) of the zeolitic rock: Z – zeolite minerals (heulandite, clinoptilolite); Qz – quartz; F – feldspars.

of a eutectic composition. The interaction of the soda ash with the silica forms sodium-silicate and liberates CO₂:



3.2. Firing behaviour

The three mix compositions were fired alternatively at 800, 850, 875 and 900 °C with isothermal holding times of 1 h. An X-ray powder diffraction pattern for the frit obtained after firing at 900 °C is shown in Fig. 2b. The crystalline phase shows peaks of quartz, feldspar and a new crystalline phase in the form of sodium calcium silicates. A considerable portion of the mix becomes amorphous, specified by the convex part of the curve on the X-ray diffraction pattern.

After the preliminary firing procedure at different temperatures, the obtained frits were milled and mixed with 0.4 wt.% of the foaming additive. The choice of using this amount of foaming additive is based on the results of previous studies, published in [34]. From the mix, granules were formed and foamed in a laboratory chamber furnace at different temperatures 850, 875 and 900 °C. Fig. 4 shows the results of synchronous thermal analyses of the raw mix with the foaming agent. DTA of raw mix compositions prepared on the basis of frits at various temperatures showed exothermic and endothermic effects. These effects corresponded to processes of oxidation of gas forming agents and melting of the glass phase. Increasing the firing temperature biases the exothermic effect temperature; therefore, for the frit of composition 3 (Fig. 4c), the effect occurs at 518.0 °C, whereas for frit composition 1 (Fig. 4a), the effect occurs at 537.3 °C. This temperature is conditioned by differences in the phase composition of the frits. The bias of the oxidation temperature at higher values is favourable for the foaming process because of the decreasing probability of burning out the gas forming agent. Endothermic effects related to the processes of forming silicates and crystallization (allegedly forming wollastonite) is also displaced in areas of higher temperatures with an increased zeolite content in the mix and under increased

Table 1
Chemical composition of the raw materials.

Raw materials	Oxide content (wt.%)									
	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO + MgO	MnO	R ₂ O	P ₂ O ₅	SO ₃	LOI
Sand sludge	69.67	0.47	7.12	3.93	7.75	0.09	2.66	0.15	0.03	0.16
Zeolitic rock	71.5	0.2	13.1	0.9	2.1	1.07	5.03	0.033		

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