



Effect of perlite waste addition on the properties of autoclaved aerated concrete



Agnieszka Różycka*, Waldemar Pichór

AGH University of Science and Technology, Faculty of Materials Science and Ceramics, Department of Building Materials Technology, al. Mickiewicza 30, 30-059 Kraków, Poland

HIGHLIGHTS

- The EPW can be used as a quartz sand replacement in the production of AAC.
- The EPW has positive influence on the formation of calcium silicate hydrates.
- Replacing the quartz sand by EPW has a positive effect on the thermal conductivity of AAC.

ARTICLE INFO

Article history:

Received 11 October 2014
Received in revised form 25 April 2016
Accepted 5 May 2016
Available online 20 May 2016

Keywords:

Expanded perlite
Waste
Autoclaved aerated concrete
1.1 nm tobermorite

ABSTRACT

In presented paper, the influence of expanded perlite waste on the properties of autoclaved aerated concrete (AAC) was investigated. Expanded perlite waste was used as a quartz sand replacement in conventional AAC mixtures at 5%, 10%, 20%, 30% and 40% by weight. Results show that use of expanded perlite waste in AAC caused a unit weight decrease in the produced AAC, it is connected with the changes in the properties of AAC. The thermal conductivity coefficient and compressive strength of specimens decreased as the amount of expanded perlite waste increased in AAC. The introduction of perlite waste up to 10% by weight reduced the thermal conductivity about 15% without significant reduction of compressive strength. Further improvement of thermal conductivity may be obtained by the addition of perlite waste up to 30%, but it caused reduction compressive strength about 20%. The minimum thermal conductivity value was 0.074 W/m·K, observed at 40% expanded perlite waste replacement. The structural and microstructural investigations showed that expanded perlite waste has a positive influence on the formation of calcium silicate hydrates (1.1 nm tobermorite) in AAC. From this result, it was concluded that expanded perlite waste can potentially be used as quartz sand replacement in the production of AAC.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

Perlite is naturally occurring aluminosiliceous amorphous volcanic rock. Raw perlites when heated to a suitable temperature (above 870 °C) expand and transform into a cellular material of low bulk density. This expansion process is due to the presence of two to six percent combined water in the crude perlite rock. Upon rapid heating, water held within the perlite vaporizes and creates bubbles in the heat softened rock. During this process perlite expands up to 15–20 times of its original volume and produce frothy-like microstructure [1]. This microstructure gives the material a set of favourable properties such as excellent insulation properties, low density and high porosity causing the expanded perlite one of the most popular lightweight mineral filler [2–13]. In 2012,

the global perlite production registered was 2.66 million tons [14]. China accounted for just over 27% of the world's total perlite production volume and was the dominant perlite manufacturer. China was followed by Greece, the USA and Turkey [14]. The global perlite production is expected to post stable growth in the years ahead and to exceed 3.05 million tons in 2016 [14]. This growth is predicted to be stimulated by the constantly increasing demand worldwide along with new capacity introductions.

One of the main problems associated with the production of expanded perlite is a formation of relatively large quantities of the fine fraction (about 5–10%) with a particle size below 200 µm. The resulting lightweight waste due to a large specific surface area and dustiness is very difficult to dispose, especially in dry conditions and so far didn't find effective applications. Expanded perlite waste has a volume character and in most cases storage capacity in the areas of production has been exhausted; therefore, it has become necessary to develop a method for its utilization.

* Corresponding author.

E-mail address: ar@agh.edu.pl (A. Różycka).

Expanded perlite waste contains in its chemical composition significant amounts of SiO_2 (65–75%), and therefore can be an attractive addition replacing part of the raw materials in autoclaved aerated concrete (AAC) technology. Autoclaved aerated concrete is widely used as building material because of excellent insulation properties and relatively high compressive strength despite a very low bulk density. Generally, aerated concrete is usually made from a mix of quartz sand and/or fly ash, cement, lime, gypsum and aluminum powder which acts as a pore forming agent. The specific surface area of the quartz sand plays an important role in the production of autoclaved concrete, in most cases the quartz sand is ground to the required fitness by ball milling. This process is energy consuming. Many studies have been reported that the hydrothermal reactions in the $\text{CaO-SiO}_2\text{-H}_2\text{O}$ system are controlled by the dissolution of quartz; the results showed that finer sand reduces AAC processing time [15–17]. The amorphous expanded perlite waste can be considered as an alternative siliceous material for ground to the relatively high specific surface area quartz sand. It should be noticed that in AAC technology, sand is wet milled which provides a practical solution to the problems with occurring during utilization of perlite waste dusting.

Mechanical properties and durability of AAC significantly depend on a major constituent in autoclaved concrete, calcium silicate hydrate –1.1 nm tobermorite. A decisive influence on the synthesis of calcium silicate hydrates has a SiO_2 modification. Amorphous expanded perlite waste due to higher solubility than quartz, can have a positive effect on the synthesis of calcium silicate hydrates formed in the AAC and consequently on the mechanical properties the material. On the other hand, synthesis of calcium silicate hydrates besides CaO/SiO_2 molar ratio, SiO_2 modification, reaction time and temperature is strongly influenced by the presence of small amounts of admixtures [18–22], so the other important factor to consider is influence of available Al_2O_3 , Fe_2O_3 and alkalis contributed by expanded perlite waste on the synthesis of calcium silicate hydrates. Much literature concerning the use of expanded perlite in the technology of building materials, investigates the effects of expanded perlite on the properties of lightweight concrete [2–4,23]. In concrete, expanded perlite is used instead of fine aggregate with various replacement ratios depending on required strength. The test results indicate that compressive strength and modulus of elasticity decrease with increasing perlite content in the concrete mixture. Moreover, water absorption and sorptivity coefficient, increase with the higher perlite contents [4]. Replacing normal aggregate by the expanded perlite reduced the thermal conductivity of the mixtures as a result of the porous structure of the perlite [4]. Yu et al [24], investigated the influence of raw perlite powder on the strength of concrete, using perlite powder as cement replacement. Their results showed that perlite powder has a significant pozzolanic effect and improved the strength of concrete.

Although extensive studies of the use of expanded perlite in lightweight concrete technology have been reported, the possibility of using this material in AAC technology has not been investigated. In recent years, the tendency to replace the traditional raw materials in AAC production by industrial wastes has been appeared [25–40]. Wastes were considered as partial replacements for the binder or quartz sand. The objective of present work was to investigate the effect of expanded perlite waste used as a substitution of ground quartz sand on the properties of autoclaved concrete. Perlite waste was used to replace part of quartz sand at 5, 10, 20, 30 and 40% by weight, respectively. Potential advantages of the use expanded perlite waste in AAC technology are primarily environmental and economic benefits. Utilization of perlite waste in AAC, could enable reduce production costs of AAC attributed to the reduction of energy consumption during the milling process, and moreover, reduce the amount of residual waste in landfills.

2. Materials and methods

2.1. Materials

Samples of autoclaved concrete with different amount of perlite waste were obtained on a laboratory scale, according to Polish technology of AAC production – UNIPOL. Characteristic for the UNIPOL technology is activation part of quartz sand (in an amount of about 20% relative to the total amount of sand) by milling to relatively high specific surface area i.e. about 4000–6000 cm^2/g (Blaine'a), what accelerates reaction of silica with the binder. In presented work, standard quartz sand was ground in laboratory mill to specific Blaine surface area of 5000 cm^2/g and 2000 cm^2/g , respectively. The surface area of the ground quartz sand corresponds to the typical surface area sand used in the production of autoclaved concrete in industrial scale, i.e. 5000 cm^2/g (activated quartz sand) and about 2000 cm^2/g in the wet ground slurry. The cementitious material used in this study was Ordinary Portland Cement (OPC) CEM I 42.5R. Pure p.a. calcium carbonate from POCH (Poland) was used as CaO source. It was calcined at 1000 °C for 2 h. The efficiency of decarbonation was tested by XRD method. In the concrete production network water was used. Commercially available aluminum powder with mating surface 6200 cm^2/g was used as pores producing agent. Table 1 presents the chemical compositions of the expanded perlite waste. The chemical composition of the waste is mainly SiO_2 . Specific Blaine surface area of the expanded perlite waste was 13,000 cm^2/g .

The particle size distribution of expanded perlite waste and ground quartz sand determined by laser particle size analyzer is presented in Fig. 1. Quartz sands are characterized by smaller particle size compared to expanded perlite waste, which contains particles with size up to 1000 μm .

Fig. 2 shows XRD analysis expanded perlite waste. X-ray diffraction study indicated the presence of amorphous glassy matrix as well as some amounts of aluminum silicate and calcium aluminum silicate. Fig. 3 presents SEM observations of expanded perlite waste and quartz sand. As shown in Fig. 3(c), expanded perlite waste exhibit a frothy-like structure with numerous open pores, that gives it a great specific surface area. SEM observations confirm the results of particle size distribution analysis; expanded perlite waste (Fig. 1 c) is characterized by coarser grains compared to ground quartz sand (Fig. 1a and b).

2.2. Mix proportion

The reference mix was composed of OPC, lime, quartz sand and water. The sand was replaced by expanded perlite waste at levels of 5%, 10%, 20%, 30% and 40% by weight. Aluminum powder was added at 0.3% by weight of the binder (OPC + lime). The mix proportions are summarized in Table 2. While mixing the dry mixes with water, it was observed that along with increased content of expanded perlite additive in the mix (at the same consistency), the water to solids ratio (w/s) was also increased from 0.48 to 1.40. The increase in w/s is attributed to porous microstructure and high specific surface area of expanded perlite what is associated with higher water demand. The AAC samples were prepared by the following procedure. First, the weighed raw solid materials were mixed with water for 2 min. Next, aluminum powder was added and mixed with the slurry for another 20 s. The obtained slurry was casted into preheated steel molds of 100 × 1000 × 100 mm and hardened at the temperature of 60 °C for 2 h. In the next step, samples were put into laboratory autoclave. Hydrothermal synthesis was carried out in the saturated steam pressure at a temperature 180 °C; the duration of isothermal curing was 12 h.

2.3. Testing procedure

After autoclaving the samples were dried and examined. Phase composition of samples was investigated using XRD. Powder XRD patterns were carried out using a Philips Xray diffractometer X'pert system with monochromatic CuK_α radiation. The microstructure of synthesized samples was observed using SEM. Low vacuum FEI NanoSEM 200 microscope was used. In order to avoid charging of the samples, a thin layer of carbon was deposited onto observed surfaces. The bulk density and compressive strength tests were conducted according to EN 772-13 [41] and EN 772-1 [42], respectively. For each mix proportion, a set of six samples were used to determine the compressive strength and the bulk density. The thermal conduc-

Table 1
Chemical composition of expanded perlite waste.

Composition	%, (by weight)
SiO_2	70
Al_2O_3	14
$\text{K}_2\text{O} + \text{Na}_2\text{O}$	7.6
MgO	0.2
Fe_2O_3	2.4
CaO	3
LOI	1.7

Download English Version:

<https://daneshyari.com/en/article/255819>

Download Persian Version:

<https://daneshyari.com/article/255819>

[Daneshyari.com](https://daneshyari.com)