

# WASTE – FREE PRODUCTION OF GAS SILICATE BLOCKS

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## INTRODUCTION

Autoclaved aerated concrete (AAC) masonry products are very popular in the construction market and are currently widely used. However, the production of such masonry products inevitably generates two types of waste: “off cut” of non-autoclaved aerated concrete (ACW) which are formed by trimming the mass from the molds before hydrothermal treatment and autoclaved aerated concrete, which remain on the mold base after autoclaving (AACW) [1–3]. It is known that about 3–5% of the latter waste is generated and recovery of it is not fully resolved [1, 3]. Therefore the aim of the study was to investigate the possibility of using AACW as an admixture in the production of new AAC – gas silicate blocks.

## MATERIALS AND METHODS

The following composition of the mixture (AC0) was chosen: cement – 17.5, lime – 12.5, gypsum – 2.5, sand slurry – 50.0, ACW slurry – 20, aluminum paste – 0.11. The water/solids ratio was equal to 0.8. The sand in the forming mixture was replaced by 6.25 % (AC1), 12.5 % (AC2) and 18.75 % (AC3) of AACW during research. All required components of forming mixture were weighed and mixed in the high speed vertical propeller stirrer of 5 m<sup>3</sup> volume by the speed of 1500 rpm. First, required quantities of sand and ACW slurries were mixed with water together. Second, Portland cement, lime, gypsum and AACW were added. Finally, aluminum paste suspension was placed. Overall mixing time was 5 minutes. Fresh AAC mixture then was poured into the steel molds 100x100x100 mm and kept in its until samples acquire the required plastic strength. The samples were hardened in a laboratory autoclave *Parr instruments* (Germany) of 4 l capacity with a saturated water vapor temperature of 190 °C and an isothermal holding time of 11 h. After hardening, the samples were removed from molds and dried to constant mass at 105 ± 5 °C.

Simultaneous thermal analysis (STA: differential scanning calorimetry – DSC and thermogravimetry – TG) was carried out on LINSEIS STA PT1600 with ceramic sample handlers and crucibles of Al<sub>2</sub>O<sub>3</sub>. At a heating rate of 10 °C/min, the temperature ranged from RT up to 1000 °C under N<sub>2</sub> atmosphere. The weight of the powder sample was ~10 mg.

The X-ray powder diffraction (XRD) data was collected with a DRON-6 powder X-ray diffractometer with a Bragg-Brentano geometry by using Ni-filtered Cu K $\alpha$  radiation and a graphite monochromator operating with the voltage of 30 kV and the emission current of 20 mA. The step-scan covered the angular range of 5–75° (2 $\theta$ ) in the steps of 2 $\theta$  = 0.02°.

The compressive strength of AAC samples was determined according to the requirements of the standard [4]. The press MEGA 10-400-50 (FORM+TEST GmbH) was used.

The volume density of the samples was determined according to the requirements of the standard [5].

## RESULTS AND DISCUSSION

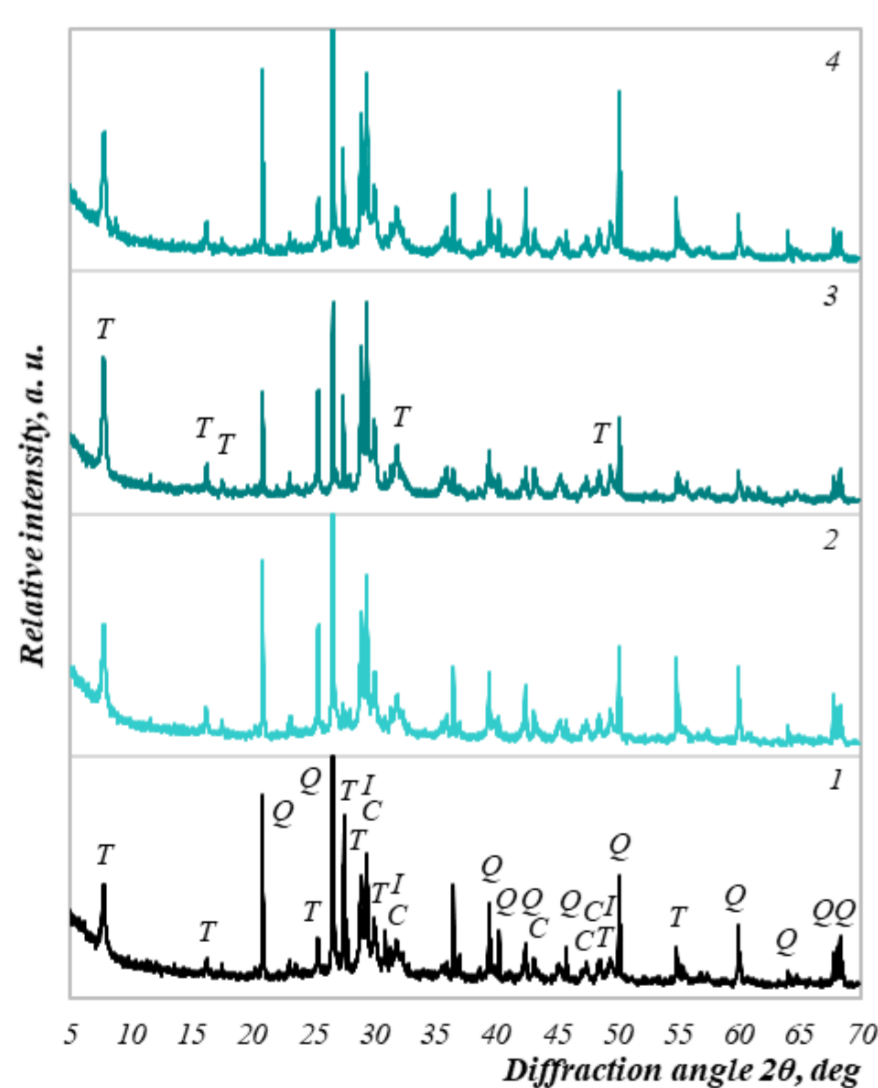
According to obtained results samples in which 12.5% of the sand is replaced by AACW have the highest mechanical strength and sufficient density (Table 1). As the amount of AACW in the sample increases, its porosity increases (Fig. 1) resulting a decrease in its density. The results of compressive strength can be explained by the data obtained during X-ray diffraction analysis. The XRD patterns of AAC (Fig. 2) indicates that the dominant compounds are quartz, calcite and tobermorite. With increasing amount of additive in sample up to 12.5% the intensity of tobermorite mineral patterns increase and intensity of the patterns characteristic of quartz decreased. It is known that the compressive strength of AAC mainly depends on the quantity and quality of tobermorite group minerals (semi crystalline C-S-H (I) and 1.13 nm tobermorite), which forms during the hydrothermal treatment. The higher amount (18.75%) of solidified waste in the forming mass prevents the quartz to form compounds which ensures strength of sample.

**Table 2.** Mechanical properties of AAC samples

Sample	Blowing height, %	Density, kg/m <sup>3</sup>	Compressive strength, MPa
AAC0	28	540	2.20
AAC1	28	546	2.25
AAC2	29	535	2.50
AAC3	30	530	1.80



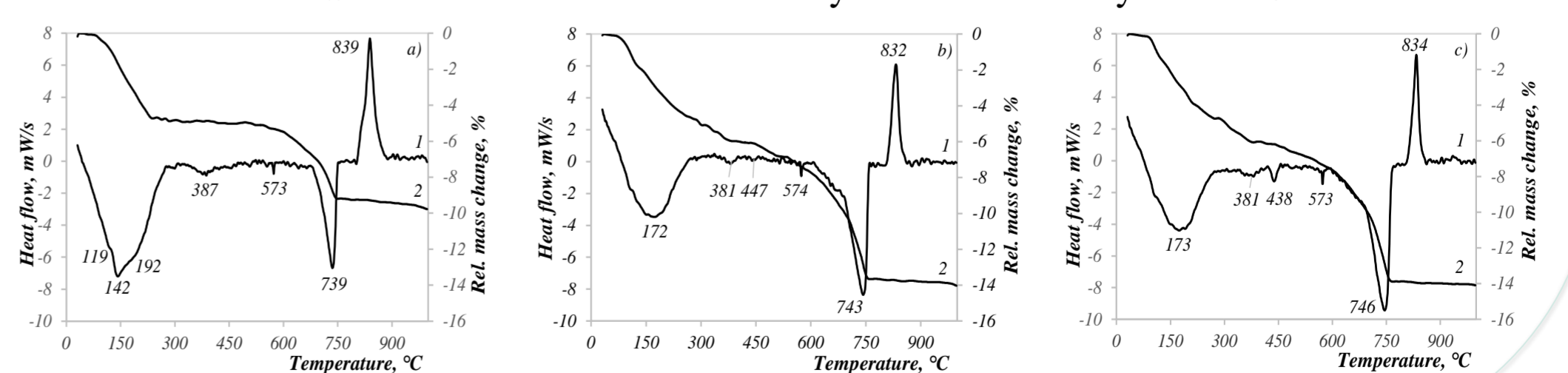
**Fig. 1.** Electron microscopy images of AAC0 (a), AAC3 (b) and AAC4 (c) samples



**Fig. 2.** X-ray diffraction patterns of AAC samples: 1 – AAC0; 2 – AAC1; 3 – AAC3; 4 – AAC4. Indexes: T – tobermorite; Q – quartz; C – calcite; I – C-S-H (I).

The thermal analysis data (Fig. 3) indicates the characteristic features of AAC. The peaks are responsible for the dehydration of calcium hydrosilicates (within the temperature range of 40–260 °C), decomposition of calcium hydroxide (at about 440 °C), transformation of  $\alpha$ -quartz into  $\beta$ -quartz (at 573 °C), and the decomposition of carbonates (within the temperature range of 700 – 760 °C). Unfortunately, the peak at 190 °C, characteristic of tobermorite, is observed only in the curve of the industrial sample (Fig. 3a). Endothermic effect due to decomposition of carbonates is larger in the curve of laboratory sample than in the industrial. This means that the carbonization process during autoclaving in samples with AACW takes place too intensively. It can be assumed that calcium hydroxide reacts with CO<sub>2</sub> instead of reacting with the required substances. The exothermic peak at about 840 °C indicates the recrystallization of semi-crystalline calcium hydrosilicates into volastonite CaSiO<sub>3</sub>. Endothermic effect at 372 °C is characteristic for decomposition of calcium hydrogranates (we don't see them in the X-ray diffraction patterns due to small amount).

In summary, it can be stated that the data of STA confirm the data of X-ray diffraction analysis. AACW can be used successfully in the production of new AAC because the technological process does not change, and the values of compression strength and other properties are close or even better than the values of the samples without additives.



**Fig. 3.** DSC (1) and TG (2) patterns of AAC industrial (a), AAC0 (b), AAC3 (c).

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