

# Durable geocoprotective building structures from ash foam concrete for high-rise construction

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**Abstract.** The article analyzes the use of ash foam concrete filler structures based on ash from sludge combustion for high-rise construction. Physical and chemical as well as physical and mechanical studies of samples of structures made of ash foam concrete were carried out. Ash foam concrete was produced with the use of ash from sludge combustion instead of natural sand after long-term operation of building structures. The improvement of the material in thermal protection is shown. Phase changes in the structures over time which is more than 12 years are traced.

## 1 Introduction

Nowadays an important ecological task is the development of building systems for building structures including high-rise buildings. These systems should provide physical and mechanical characteristics of building structures and at the same time they would use waste as a raw material source [1-4]. One of such engineering proposals which allow to use a large of waste is their addition in building systems as raw material elements [5-7]. An example of such a system is the technology of ash utilization from sludge combustion by its addition in ash foam concrete. Ash foam concrete is a building system with partial or complete replacement of natural sand by ashes from sludge combustion.

The ash foam concrete structure was made in the form of walls of an industrial building. When manufacturing these walls, 100%, 50% and 25% of sand were replaced with ash. The purpose of the work was to study building structures over time in order to use them as filler structures for high-rise construction.

## 2 Methods

Methods of technical properties' research were based on the Russian standards. This type of standards is almost the same as the standards of other countries.

Autoclave technology (the temperature – 174°C, the pressure – 8-10 MPa) was recognized the most effective method of hardening. In this case cement, sand, building lime,

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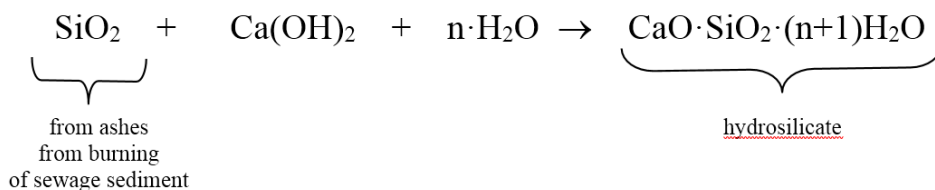
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Ca(OH)<sub>2</sub>, were used in certain ratios with certain parameters of flowability. The composition of ash foam concrete is shown in Table 1.

**Table 1.** Composition of the materials for production of autoclave ash foam concrete with medium density D500 ... D800 kg/m<sup>3</sup>.

№	medium density, kg/m <sup>3</sup>	Consumption of the materials per 1 m <sup>3</sup> of ash foam concrete, kg					water/cementing mortar
		Portland cement PC500 DO	lime	sand + ashes from sludge combustion	water	additive forming foam	
1	500	170	70	160	96	2,56	0,40
2	600	190	80	230	105	2,42	0,39
3	800	210	80	410	110	2,15	0,38

This choice was made because of the high-surface area of ashes from sludge combustion which allows to use ash instead of a part of natural sand that is required when applying wet grinding in ball mills. The reaction was realized in an autoclave provided that:



**Fig. 1.** The reaction.

This reaction provided strength and main operational properties of the stone formed.

### 3 The experiment and results

During the experiment physical, chemical and mechanical studies of ash foam concrete test pieces with various percentage of ash were carried out after 12 years of their service:

test piece № 1 – the replacement of 25% of quartz sand by ashes from sludge combustion in ash foam concrete D500;

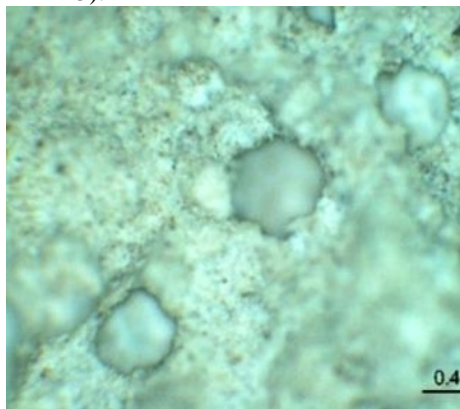
test piece № 2 – the replacement of 50% of quartz sand by ashes from sludge combustion in ash foam concrete D500;

test piece № 3 – the replacement of 100% of quartz sand by ashes from sludge combustion in ash foam concrete D500.

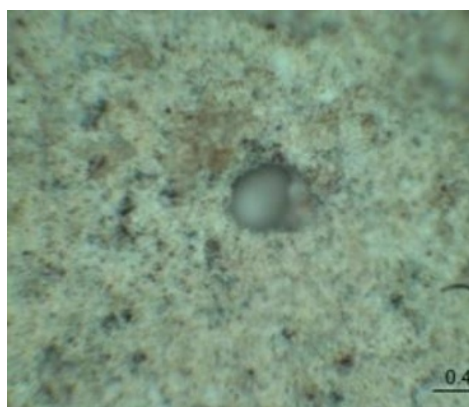
Ash foam concrete hardened in an autoclave at a temperature of 174°C and pressure of 1 MPa.

The studies conducted under the “Altami MET 6C” metallographic microscope at 5X power showed that, when increasing the percentage content of ash in the material, the nature of

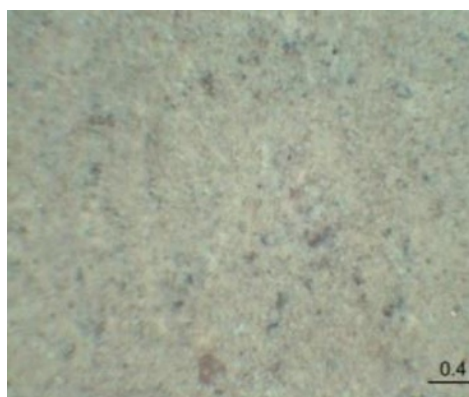
pores changed. They became smaller (see Figure 1 for test piece № 1; Figure 2 for test piece № 2; Figure 3 for test piece № 3).



**Fig. 2.** Test piece № 1 of ash foam concrete at 5X power.

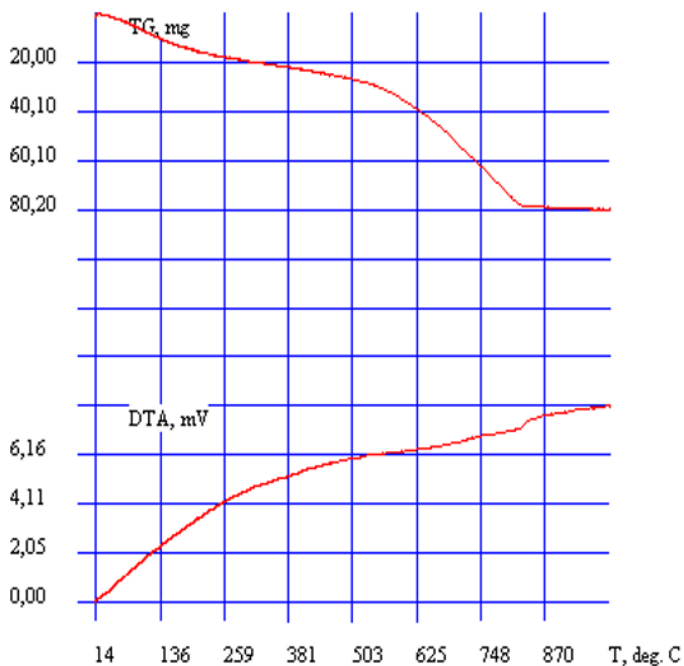


**Fig. 3.** Test piece № 2 of ash foam concrete at 5X power.

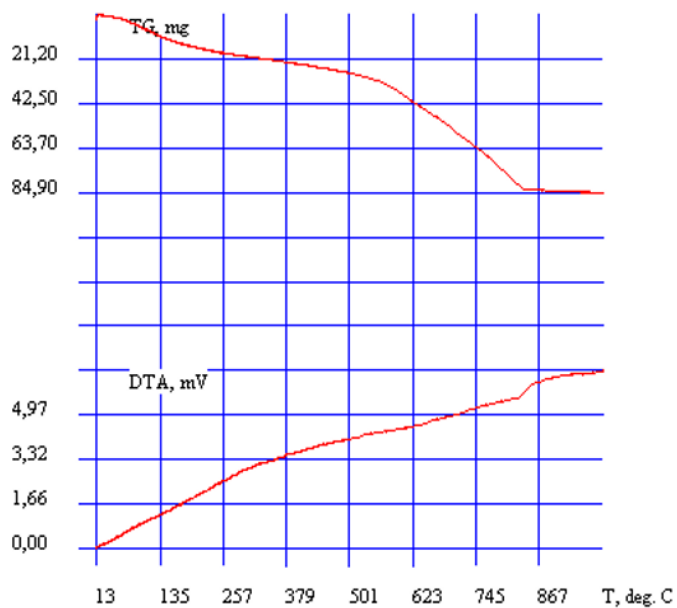


**Fig. 4.** Test piece № 3 of ash foam concrete at 5X power.

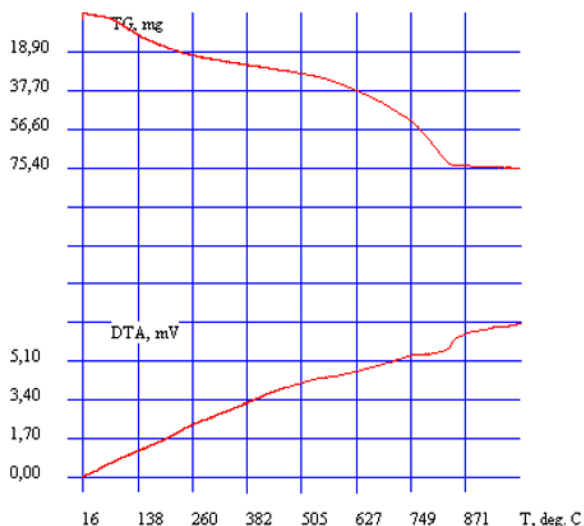
Derivatographic analysis of the received ash foam concrete test pieces at the age of 12 years from the date of their manufacture was performed on the derivatograph “Q-1500D”. Its results are presented in Figures 5-7.



**Fig. 5.** The results of the analysis of ash foam concrete test piece by means of “Q-1500D” derivatograph after 12 years of its operation (test piece № 1, weight – 0,320 gr., response – 100).

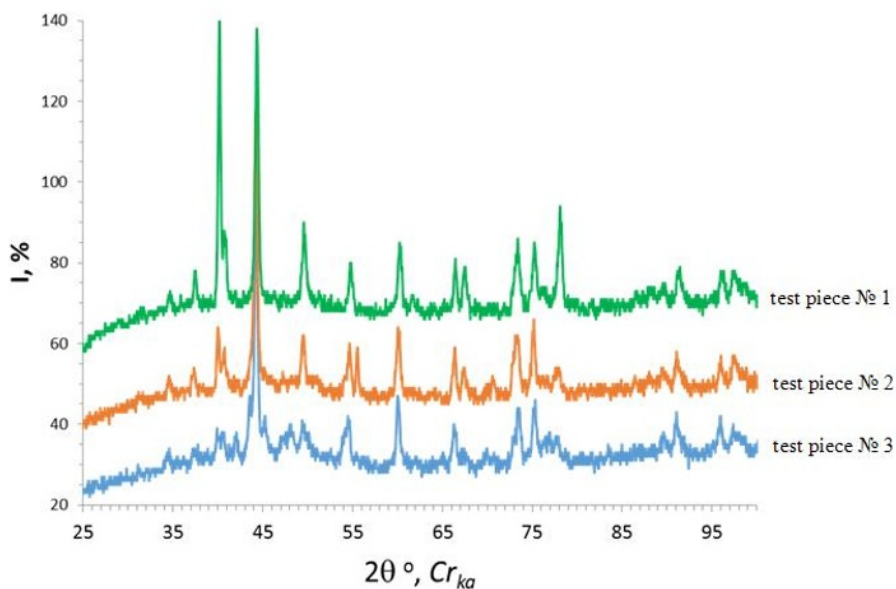


**Fig. 6.** The results of the analysis of ash foam concrete test piece by means of “Q-1500D” derivatograph after 12 years of its operation (test piece № 2, weight – 0,308 gr., response – 100).



**Fig. 7.** The results of the analysis of ash foam concrete test piece by means of “Q-1500D” derivatograph after 12 years of its operation (test piece № 3, weight – 0,305 gr., response – 100).

The data showed that over time stabilization is observed in the test pieces in which there was the replacement of quartz sand by ash from sludge combustion if 25%, 50% and 100% of natural sand were replaced. According to the thermogram total water losses were approximately equal in all test pieces of ash foam concrete. Provided that total water losses were the same, redistribution of hydrated phases was possible towards low-basic hydrosilicates. This confirmed an endothermic effect at a temperature 800°C which is characteristic of low-basic hydrosilicates. The portable X-ray diffractometer “Diffrey-401” was used to carry out non-destructive X-ray diffraction analysis of all samples. The results of the studies are given in Figure 8.



**Fig. 8.** The results of X-ray phase analysis of ash foam concrete test pieces after 12 years of their operation.

X-ray phase analysis showed that, when increasing the percentage of ashes from sludge combustion in ash foam concrete, the (40) reflection at  $2\theta$  disappeared. This effect might be identified as calcium hydroxide,  $\text{Ca}(\text{OH})_2$ , formation. That is why a decrease of this phase was followed by the formation of low-basic hydrosilicates (the ratio of  $\text{CaO}$  to  $\text{SiO}_2$  was 0,8-1,5). The formed hydrosilicates could be amorphous therefore they didn't appear on the diffraction patterns. Changes in reflection intensity in the range of 50 and 55 at  $2\theta$  which are typical of iron oxide,  $\text{Fe}_2\text{O}_3$ , were also observed. It should be noted that iron oxide is present in ashes from sludge combustion. The drop of the (78) reflection at  $2\theta$  might arise from a decrease of  $\text{SiO}_2$  crystals in the system because of the replacement of quartz sand by amorphous ash. Thermophysical studies of ash foam concrete structures in thermal conductivity showed that while the percentage of ash content in ash foam concrete increased the coefficient of thermal conductivity decreased and had a value of  $\lambda=0,11\text{Vt/mC}$  for test piece № 1,  $\lambda=0,10\text{Vt/mC}$  for test piece № 2,  $\lambda=0,09\text{Vt/mC}$  for test piece № 3. Sound-proofing properties of ash foam concrete were also improved with an increase of ash content percentage [8-9]. The data given in the paper allow stating that building structures from ash foam concrete are referred to nonwaste production which enables to use waste from housing and public utilities, namely ashes from sludge combustion, in building systems as a raw material source when producing ash foam concrete. At the same time ashes are utilized, yards are freed; a durable and useful material is produced for high-rise construction and transport infrastructure [10-11]. Building structures from ash foam concrete can be used as filler ones for high-rise construction as they have low thermal conductivity coefficient at equal medium density of a material.

Such a "chemical" behavior of ashes from sludge combustion over time can be explained in terms of the composition, namely the presence of iron oxide,  $\text{Fe}_2\text{O}_3$ , in ash which has a high level of acceptor properties due to Fe(III) content. This corresponds to the value of orbital electronegativity which is 2,22 eV. This fact allows supposing that electrons of Fe(III) are active sites, their role in formation of a surface activity being extremely high. Besides, this assists to increase stability of a system [12-19].

In proceedings [20-22] geocoprotective aspect of technogenic mineral substance use can be traced which, with reference to publications, can serve as mineral geoantidotes after their basic life cycle. Thus, in accordance with works, one can assume that decay products of ash foam concrete building structures of the type considered above have a higher capacity to neutralize heavy metal ions. This increases the geocoprotective significance of building systems using ash from sludge combustion.

## 4 Conclusions

1. Ash foam concrete building structures were analyzed over time which was more than 12 years. It has shown that these structures are durable.
2. Ash foam concrete changes its structure with an increase in the percentage of ash from sludge combustion while the amount of chemically bound water remains the same. As a result the structure of ash foam concrete has smaller pores.
3. It is believed that such building structures can be used for high-rise construction as filler or lightweight mansard ones. This will result in energy savings due to increased thermal insulation properties.

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