Influence of silica-containing additives on structure formation of composite cement binder for non-autoclaved aerated concrete

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Abstract. The article presents the results of a study of the effect of silica-containing fillers on the structure formation of a composite cement binder. Obtaining results allows the use of active fillers in cement sources, which allows to reduce the proportion of binder without loss of density, which is the result of using the resource of energy-saving research technologies in the field of building material.

1 Introduction

The development of composite building materials requires the creation of highly effective multifunctional cement binders. The theoretical and experimental studies carried out in the field of improving the quality of the cement binder allow us to conclude that the most optimal is the use of finely dispersed natural and technogenic mineral fillers [1–4].

Numerous studies of filling the cement system with mineral fillers of optimal dispersion have shown the possibility of changing the processes of hydration and hardening of cement, as a result of which the structure of the cement stone improves and the physical and mechanical properties of the final product increase. In this regard, it is of scientific and practical interest to conduct research on the control of the structure formation of cement systems using mineral fillers with a wide spectrum of action. In this direction, numerous studies have been carried out on the development and application of natural and artificial silica-containing materials for the production of binder mixtures [5–12].

The conducted research in the field of composite binders showed that the physical and mechanical properties of the cement binder depend on the crystallization of hydrate neoplasms and pores that form the microstructure of the material. The study of the microstructure of non-autoclaved aerated concrete with silicon-containing mineral fillers is the most promising, which, according to the authors of [5], exhibit the highest hydraulic activity.

2 Objects and methods of research

To study the processes of hydration of the filled cement binder, the fracture surface of the material was studied using a scanning ion-electron microscope.

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Micrographs of the fracture surface of the cement stone without additives are shown in Fig. 1. As can be seen from fig. 1, additive-free cement stone is composed of calcium hydrosilicates, sulfohydroaluminates and calcium hydrosilicates. Neoplasms are present in the pores, but complete overgrowth of the pores is not observed.

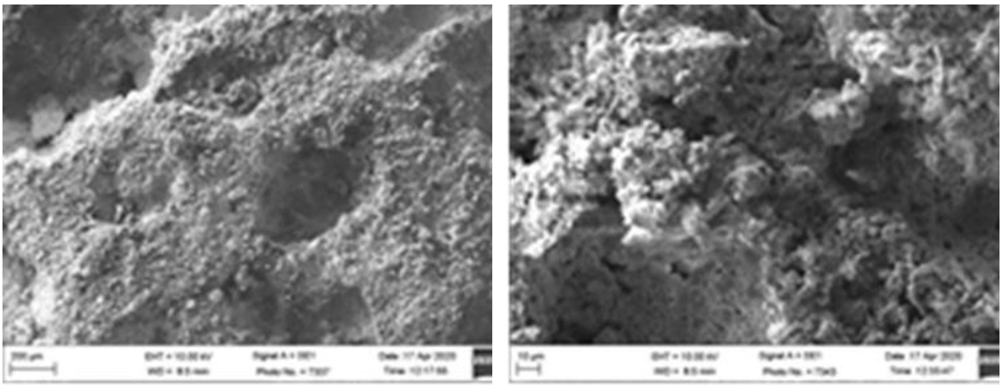

Fig. 1. Microphotographs of the fracture surface of a cement stone without additives obtained at the age of 28 days

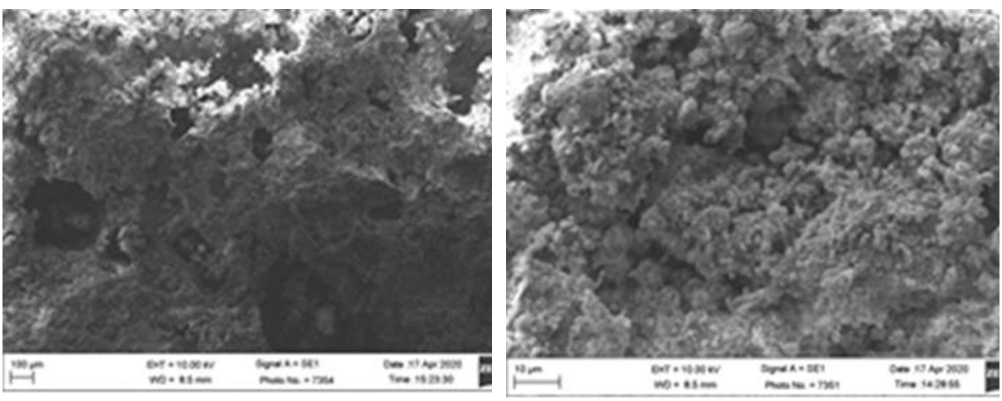

Fig. 2. Micrographs of the fracture surface of cement stone with fly ash + superplasticizer obtained at the age of 28 days

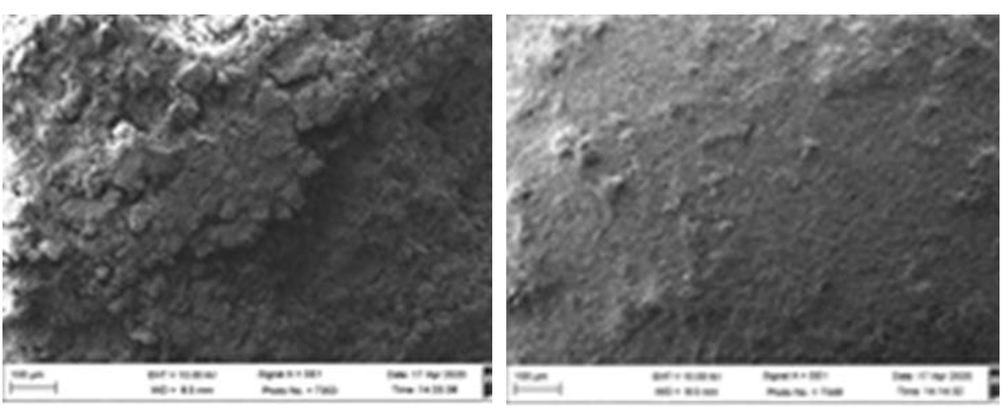

Fig. 3. Micrographs of the fracture surface of composite (microsilica + fly ash + superplasticizer) cement stone, obtained at the age of 28 days

On fig. 2-3, it can be seen that in the samples of the composite binder at the age of 28 days, with the addition of silica fume, an increased homogeneity of the monolith with a pronounced dispersed phase is observed. The next feature is the high density of the cement stone structure without visible defects. During structure formation, an increasing ability to sealing properties of finely dispersed silica is observed. On fig. 2-3 along the contact zone, borders consisting of phases of neoplasms are clearly visible. Pore structure of cement stone with a predominance of micropores.

The introduction of the complex additive fly ash + microsilica + Polyplast undoubtedly introduces its own peculiarity into the process of structure formation of cement stone.

Based on the above features of structure formation, due to the mechanism of action of the polyplast additive in combination with the addition of microsilica + fly ash, the strength of the cement stone increases due to the pozzolanic-active effect of the hardening system.

At the same time, an X-ray phase analysis was carried out of a cement stone without additives and composite binders with various silica-containing additives. The research results are presented in fig. 4-6.

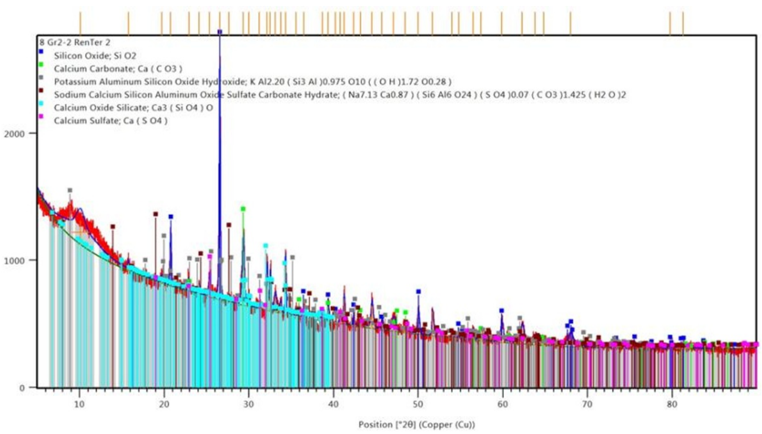

Fig. 4. X-ray diffraction pattern of a cement stone without additives

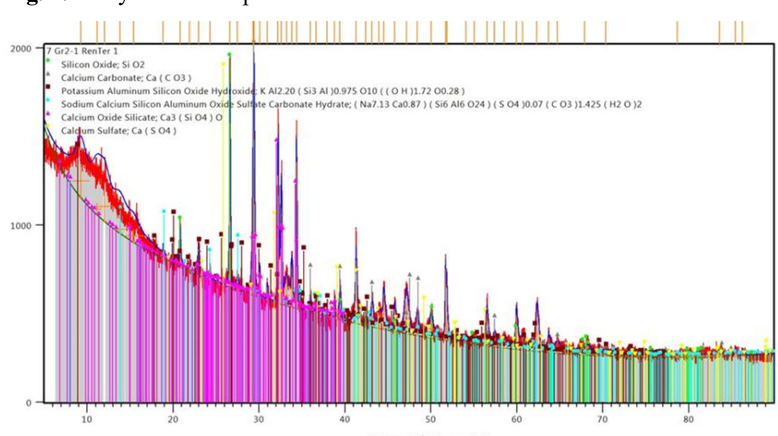

Fig. 5. Diffraction pattern of cement stone with fly ash + SP

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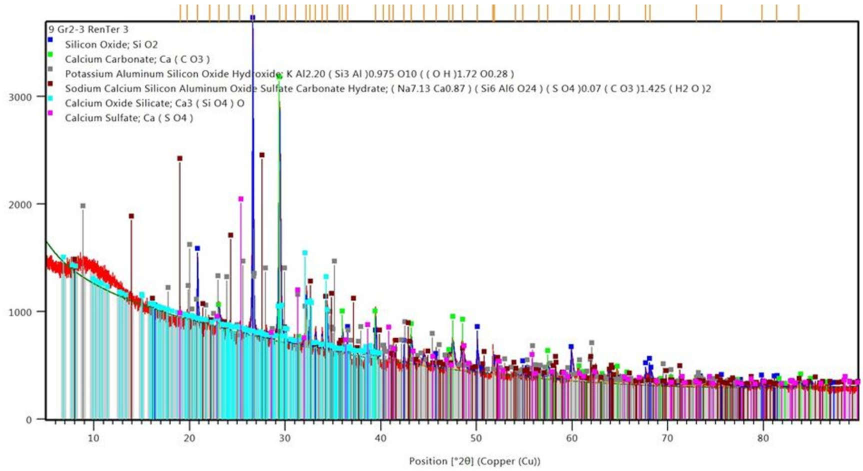

Fig. 6. Diffraction pattern of cement stone with fly ash + SP + microsilica

3 Results and their discussion

The results of studies of the mechanism of action of FA and fly ash in the composition of cement are one of the key features of the structural phases of neoplasms and their morphology. For the processes of cracking in the structure of concrete, it is necessary to control and reduce the concentration of internal stresses during the structure formation of cement stone.

As studies have shown with the introduction of fly ash and microsilica into the cement system, a large number of stable low-basic calcium hydrosilicates have been formed that can reduce the concentration of stresses, reduce their level and the risk of influence due to their own plastic deformations [9].

The influence of microsilica, fly ash, and polyplast additives on tricalcium silicate hydration products was also studied by X-ray fluorescence analysis. The samples were examined at the age of 28 days. The presence of C3S with the addition of microsilica and fly ash in the composition of hydration products has not been established neoplasms.

However, a decrease in the intensity of the Ca (OH)2 lines over time, observed on the X-ray patterns of samples with FA additives, with a simultaneous increase in the degree of C_3S hydration, indicates the reaction between lime microsilica and fly ash with the formation of amorphous products.

At the next stage of research, the distributions of the main elements (Ca, Si, Al, Fe, etc.) were studied; X-ray spectral microprobe analysis of the surface of the cleavage of cement stone and composite binders with various silica-containing additives was carried out. The quantitative distribution over the main elements and oxides is shown in fig. 7-9.

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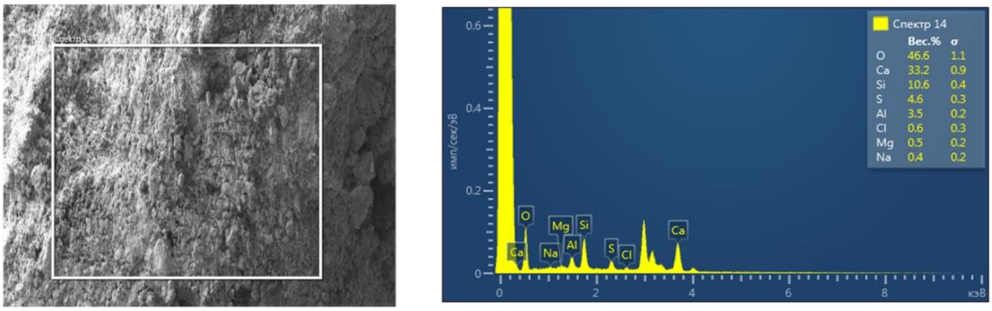

Fig. 7. Features of the formation of the microstructure of cement stone at the age of 28 days

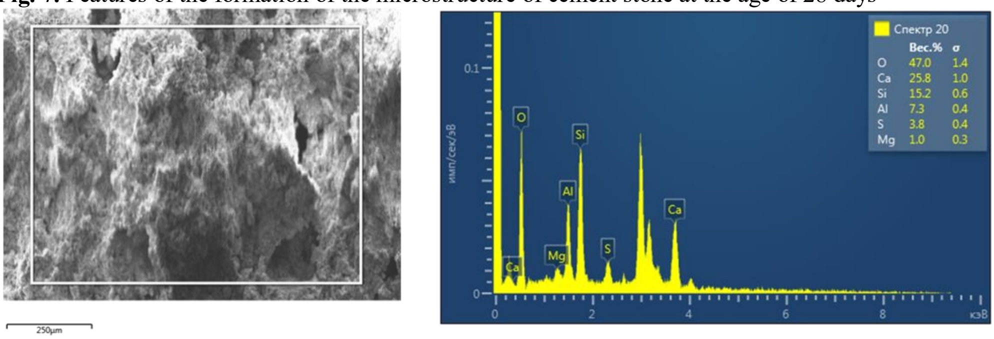

Fig. 8. Features of the formation of the microstructure of cement stone with fly ash + SP at the age of 28 days

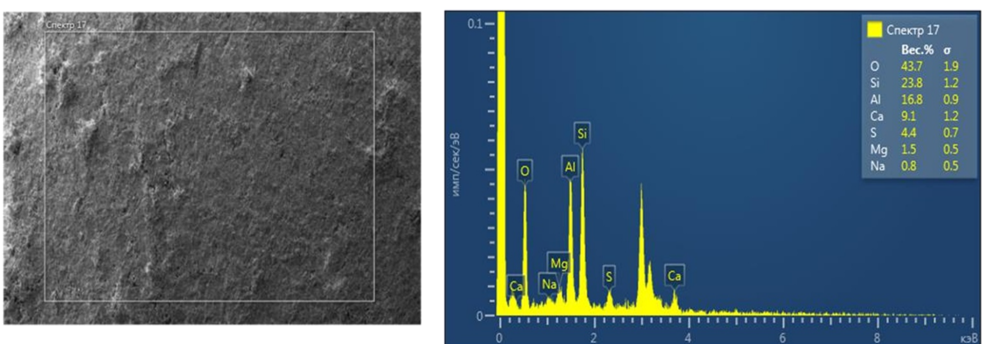

Fig. 9. Features of the formation of the microstructure of cement stone with fly ash + microsilica + SP at the age of 28 days

The results of the analyzes attached to fig. 7-9 show a regular decrease in the content of Ca and a simultaneous quantitative increase in the content of Si and Al in cement stone based on composite binders compared to cement stone without additives.

The main elements are: O, Si, Ca, Al, therefore, in the process of hydration: oxides SiO2, CaO, Al2O3 are formed. The CaO content in the cement stone without additives is higher than in the cement stone based on a composite binder. The content of Al oxides is significant and show that additional hydrate phases appear, which in turn leads to an improvement in the uniformity of the structure of the composite binder.

4 Conclusions

It has been established that the formation of low-basic calcium hydro silicates of the C-S-H(I) type during the interaction of FA and fly ash with calcium hydroxide is clearly visible at all periods of hardening. The degree of influence of MICROSILIC on the change in the phase composition of hydrates and the kinetics of structure formation correlates with the hydraulic activity and dispersion of neoplasms, and is also consistent with the values with increasing strength of the cement stone.

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