# Shrinkage deformation of cement foam concrete

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**Abstract**. The article presents the results of research of dispersion-reinforced cement foam concrete with chrysotile asbestos fibers. The goal was to study the patterns of influence of chrysotile asbestos fibers on drying shrinkage deformation of cement foam concrete of natural hardening. The chrysotile asbestos fiber contains cylindrical fiber shaped particles with a diameter of 0.55 micron to 8 microns, which are composed of nanostructures of the same form with diameters up to 55 nm and length up to 22 microns. Taking into account the wall thickness, effective reinforcement can be achieved only by microtube foam materials, the so-called carbon nanotubes, the dimensions of which are of power less that the wall pore diameter. The presence of not reinforced foam concrete pores with perforated walls causes a decrease in its strength, decreases the mechanical properties of the investigated material and increases its shrinkage. The microstructure investigation results have shown that introduction of chrysotile asbestos fibers in an amount of 2 % by weight of cement provides the finely porous foam concrete structure with more uniform size closed pores, which are uniformly distributed over the volume. This reduces the shrinkage deformation of foam concrete by 50%.

## 1. Introduction

Much attention is paid to research and development for energy conservation and its efficient use in the development program of Russia up to 2020 [1]. Currently, about 20% of energetic resources are spent for heating of buildings, about 45% of heat energy is lost through the building envelopes. Therefore, the development of structural heat-insulating materials, that are energy efficient both at the production stage and during the operation, is very important. The representative of energy-efficient wall materials is foam concrete. The research on improving production processes of foam concrete and its quality for precast and monolithic building envelope is relevant. Foam concrete is multifunctional building material that is made from inexpensive and readily available raw materials without using of imported components. Foam concrete has a relatively low average density, low thermal conductivity, high durability and it is environmentally friendly [2].

However, non-autoclaved foam concrete has significant shortcomings. For ensuring high level of quality in building structures which are made of foam concrete it is necessary to control a large quantity of technological parameters: the quality and quantity of raw materials, water solid ratio, rheology, temperature and pH environment. The process of structure formation of cellular concrete is difficult to control and regulate. The actual conditions of foam concrete structure formation often deviate from the optimum, which leads to the emergence of defects in its structure and reduction in the quality. Shrinkage strain refers to such defects. Moreover the smaller the density the greater the shrinkage deformation property is. Shrinkage strain of foam concrete with density of 300 ÷ 400 kg/m$^3$ can be up to 7 mm/m. Such high values of shrinkage strain impose very severe restrictions on the scope of the foam concrete products of natural hardening and efficiency of their use in monolithic construction [3]. The problem of obtaining non-shrinking cellular concrete of natural hardening is very relevant, but is still not solved despite of several studies [4,5, 6] has been carried out on that subject.

The primary cause of shrinkage deformation of foam concrete of natural hardening are cracks occurring in concrete's interporous partition walls during the technological processing of raw materials and hardening of the cement stone. The propagation rate and size of cracks in concrete, according to P.G. Komohov [7], are determined by its structural properties that are formed by the structure and properties of raw materials and processing methods that ensure their interaction and continuity. The energy of any loaded volume is converted into crack and leads to the destruction of the material, therefore the concrete structure must include not only the durable and fragile base, but viscoelastic inclusions, capable of absorbing the growth energy of propagating crack. Fibers are visco-elastic components, i.e. a reserve of plasticity that increases the limit of the material destruction and also has a positive effect on the features of the structure during the preparation of fiber reinforced foam mixtures by one-stage technology, and its structure formation during natural hardening [8].

Many fibers are used in concrete technology such as steel, carbon, mineral and other fibers. Earlier, the type and amount of fibers to improve the efficiency of foam concrete was determined [9]. This paper presents the results of the research of shrinkage deformation of cement foam concrete with micro-reinforcing additive in the form of chrysotile asbestos fiber with an optimal content of 2% by weight of cement.

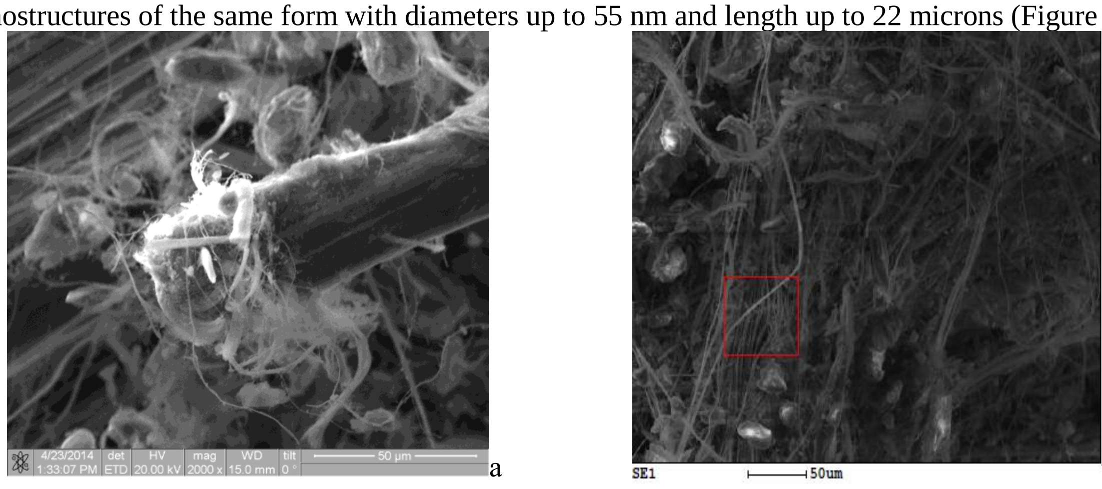
The research goal is to study the patterns of influence of chrysotile asbestos fibers on drying shrinkage deformation of cement foam concrete of natural hardening.

The research object is the hardened foam concrete with chrysotile asbestos fibers. The processes of the production of the modified foam concrete with fibers are under investigation.

## 2. The study of chrysotile asbestos fibers

Taking into account the wall thickness, effective reinforcement can be achieved only by microtube foam materials, the so-called carbon nanotubes, the dimensions of which are of power less than the wall pore diameter. One material exist in nature which comply to these requirements and can be used as dispersing reinforcement: chrysotile $Mg_3Si_2O_5(OH)_4$. This material in the fluff form of fibers has a tubular structure, and the fiber diameters are comparable in size to the thickness of the walls [10]. In this research chrysotile asbestos fiber grade A-6K-30 of Bazhenovsky field was used.

According to the data obtained from SEM Quanta 200 3D investigation it can be said that the chrysotile asbestos composed of fiber shaped agglomerations length up to 1.35 mm with a complex inner structure containing microstructures of a cylindrical shape. In Figure 1, a, scanning electron microphotograph is given of chrysotile asbestos fiber. This sample contains cylindrical fiber shaped particles with a diameter of 0.55 micron to 8 microns (Figure 1, a) which are composed of nanostructures of the same form with diameters up to 55 nm and length up to 22 microns (Figure 1, b).



a b

**Figure 1**. Microstructure of the chrysotile asbestos fiber: a – a fragment; b – general view.

With the additional consoles of SEM Quanta 200 3D, power-dispersion analyzer, it could be managed to get the elemental microanalysis of chrysotile asbestos fibers (Figure 2). The chrysotile asbestos fiber grade A-6 K-30 Bazhenovsky field is represented by oxides of silicon and magnesium (Figure 2). In addition, the chemical composition of the fiber includes a small amount of oxides of calcium, aluminum and iron.

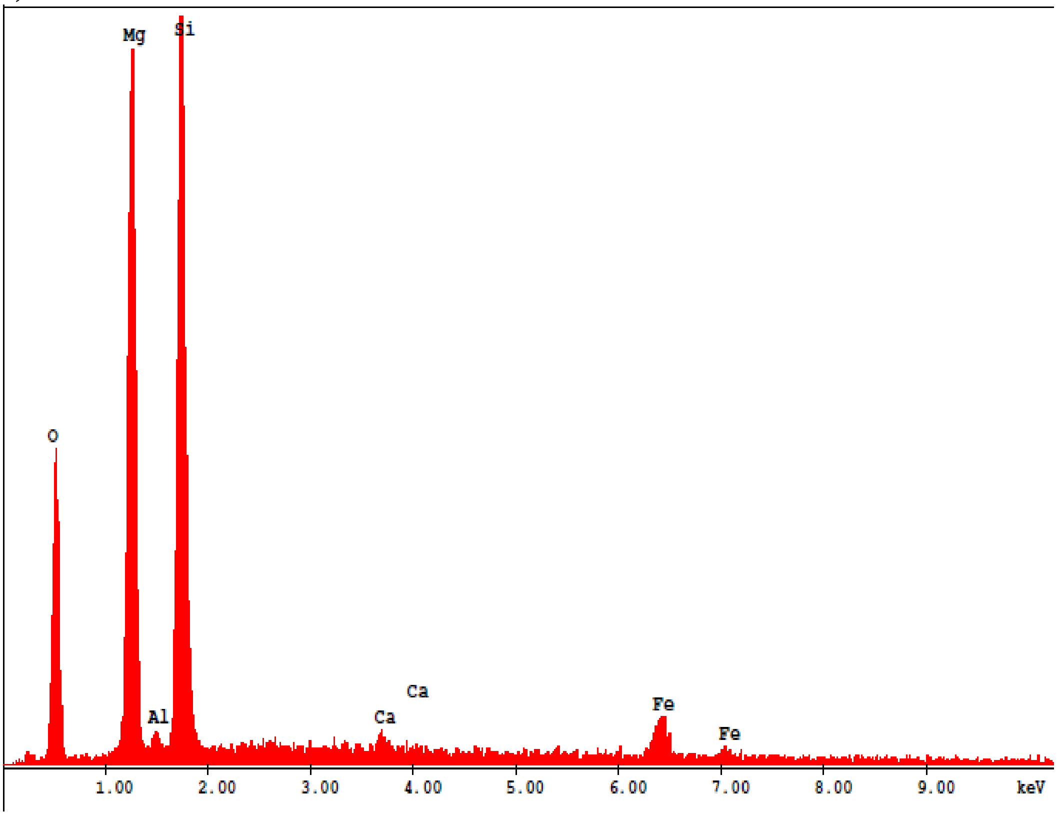



**Figure 2**. Elemental microanalysis of the chrysotile asbestos fibers.

### 3. Shrinkage of foam concrete reinforced chrysotile asbestos fibers

These fibers have been used as high-strength reinforcing element of the cement matrix to improve the physical and mechanical properties of the cement foam concrete of natural hardening. In the study was used a mixture of foam concrete, which includes: Portland cement of Topkinsky plant M500 (GOST 101178-85), quartz sand of Kudrovskoe field of Tomsk region with a fineness modulus of 1,8 (GOST 8736-93), foam agent PB-2000 (TC 2481-185-05744685-01), tap water (GOST 23732-79). The foam concrete mixture was produced by one-step technology in the laboratory mixer. For testing shrinkage strain finished concrete mix is placed in metal molds 4x4x16 cm. Molded foam concrete samples are incubated in closed desiccators over water. The testing and the evaluation of the quality of foam concrete were conducted in accordance with Russian State Standard GOST No 25485-89.

As follows from the results of the study adding chrysotile asbestos fibers in the foam concrete mixture significantly reduced shrinkage deformation of this material, up to 50% (Figure 3).

During the mixing, the fibers evenly distributed throughout the cement-sand mixture that provides spatial reinforcement throughout the foam concrete volume. Thus provides an optimization of the composition that prevents the probability of the formation and developing intrastructural defects in foam concrete [11]. Distributed chrysotile asbestos fibers in the cement foam concrete act as nucleation sites, which on the one hand lead to the development of fibrillar structure on the pore walls, which in turn ensures its continuity and uniformity (Figure 4. b), while on the other hand ensures an orderly structure orientated supermolecular sheath about the fiber. This reduces the shrinkage of foam concrete.

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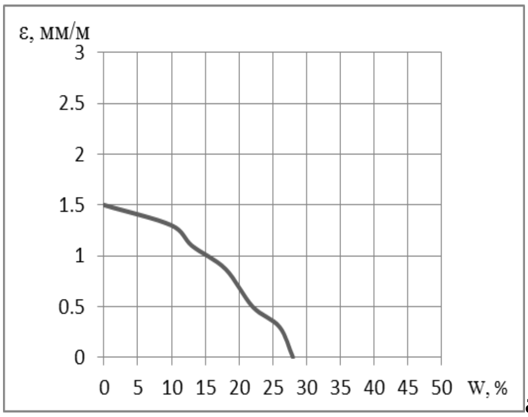
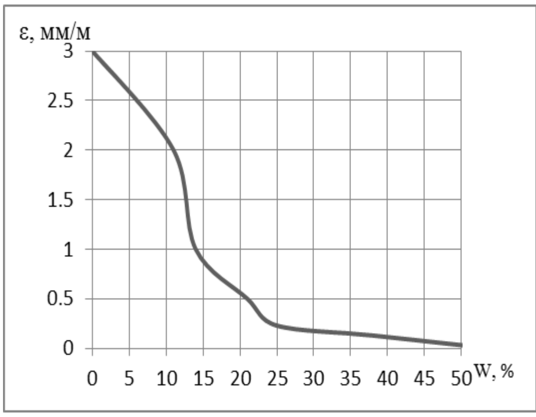
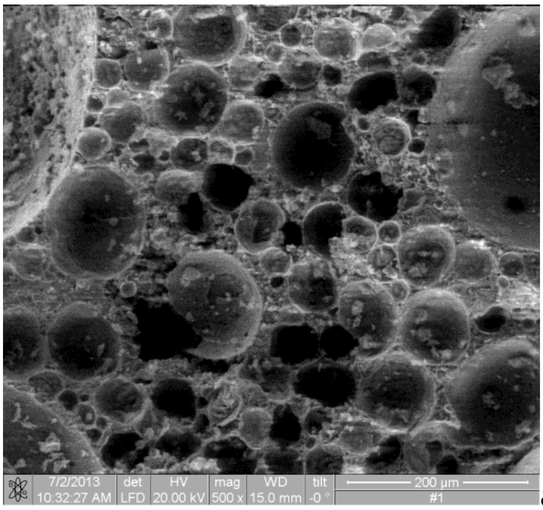


a



b

**Figure 3.** The curves of drying shrinkage of the cement foam concrete D500: a – fiber reinforced; b – without fibers.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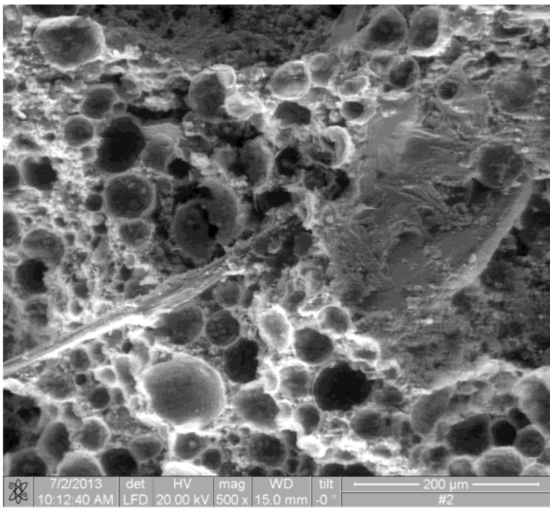
b

**Figure 4.** The structure of the cement foam concrete D 400: a – without fibers, b – fiber reinforced.

The microstructure investigation results have shown that foam concrete structure with chrysotile asbestos fibers are finely porous, with lots of uniform size and closed pores, which are uniformly distributed over the volume. The chrysotile asbestos fibers ensure the absence of pore wall percolation and stabilize its structure (Figure 4. b). In concretes without fibers, due to intensive percolation of wall pores (Figure 4. a) causes them to combine into larger ones, which in turn increases the shrinkage of the foam concrete and leads to deterioration of its operational properties. The presence of not reinforced foam concrete pores with perforated walls causes a decrease in its strength; it decreases the mechanical properties of the investigated material and increases its shrinkage. The stabilization of foam concrete structures with chrysotile asbestos fibers is mainly due to the reinforcement effect and the formation of the fibrillar structures, and due to the ordering effect of the a supermolecular structure in the pore walls.

A significant decrease in the values of shrinkage strain of the foam concrete during the natural hardening can predict a reduced level of stresses formation in the structure of foam concrete and, as a consequence, increased robustness of products made of this material. Regulations for manufacture of foam concrete with chrysotile asbestos fibers were developed.

## 4. Conclusions

The results of the investigation of the chrysotile asbestos fibers carried out by using electron microscopy showed that the fibers contain oxides of silicon and magnesium, they have the cylindric form, their diameter is of 0.55 micron to 8 microns. The fibers are agglomerated to fiber shaped agglomerates with a diameter up to 55 nm and length up to 22 microns. The introduction of the reinforcing additives (chrysotile asbestos fibers) is necessary to produce the foam concrete of natural hardening and its products with low shrinkage strain.

The findings suggest that the introduction of the chrysotile asbestos fibers to foam concrete mixture in amount of 2 % by weight of cement provides the finely porous structure with more uniform size closed pores, which are uniformly distributed over the volume. Experimental studies have established that this ensures a decrease in shrinkage deformation of cement foam concrete by 50%.

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