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Influence of Basalt Fibre on Foam Concrete Structure

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In this paper research of the structure of dispersely – reinforced basalt fibre cement stone with the purpose of getting foam concretes with improved performance characteristics is carried out. The results are given of the study of the processes of structure formation of the cement system, dispersely – reinforced by basalt fibre, consisting of a number of thinner fibres that actively interact with cement matrix in a chemisorbed manner. Interaction takes place only in the surface layer, basalt fibre integrity being preserved in the cement stone. The effect of «fullness» is observed at that and availability of cement adhesive vacuum absorption is assumed. The suggestions mentioned are confirmed by physical and mechanical tests of foam concrete samples possessing enhanced durability, frost resistance and longevity.

Keywords: dispersed reinforcement, basalt fibre, chemisorbed interaction.

Влияние базальтового волокна на структуру пенобетона

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Приводятся исследования структуры цементного камня, дисперсно-армированного базальтовой фиброй с целью получения пенобетонов с улучшенными эксплуатационными свойствами. Представлены результаты изучения процессов структурообразования цементной системы, дисперсно-армированной базальтовым волокном, которое состоит из множества еще более тонких волокон, хемосорбционно взаимодействующих с цементной матрицей. Взаимодействие происходит только в поверхностном слое с сохранением целостности базальтовой фибры в цементном камне. Отмечается эффект «наполненности» фибры.

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Вышеперечисленные предположения подтверждаются физико-механическими испытаниями пенобетонных образцов, обладающих повышенной прочностью, морозостойкостью и долговечностью.

Ключевые слова: дисперсное армирование, базальтовая фибра, хемосорбционное взаимодействие.

1. Introduction

Among the effective wall materials are foam concretes, which are currently experiencing the third revival. Foam concrete is an economical, durable, eco-friendly, biologically stable material. An ability to achieve the required density, a predetermined strength, a desired shape make it promising for manufacturing a wide range of construction products, including monolithic items. Foam concrete can be used as structural and insulation material. However, the production of foam concrete according to non-autoclave technology has a number of shortcomings and the quality of the finished product needs to be improved.

The main disadvantages of cellular concretes, particularly non-autoclave ones are: low modulus of elasticity as compared with conventional concrete, so they are more susceptible to deformation; they possess higher creepage, fragility, resulting in materials and products undesired chipping and cracks during manufacture and installation. Monolithic foam concretes are characterized by high shrinkage. This leads to rapid cracks or even products destruction.

One of the ways to overcome these disadvantages is dispersed reinforcement of foam concrete with basalt fibers, providing a significant improvement in the strength and deformation properties of the material.

2. Materials and methods

To assess the quality of the structure of cementing material of interporous partitions of fibrous foam concrete and analyse the behavior of basalt fiber in cement system in time, research of fiber and the cement stone dispersely – reinforced by basalt fibre was conducted in comparison with control samples – cement stone without the fibre.

The following studies were conducted: an X-ray phase analysis of hydration products of the cement stone, dispersely – reinforced by basalt fibre and a control sample of cement stone at the age of 28 days, as well as the fiber itself; a microstructure analysis of samples of similar compositions of 3 years of age was performed.

The fibre was analysed by means of an optical Leika DML microscope. An X-ray phase analysis was performed with D 8 ADVANCE instrument in Cu-K_2 radiation. Microstructure studies were conducted with the help of a scanning electron microscope JEOLJSM 7001F.

3. Theory

We have made the following assumptions:

– The basalt fibre, consisting of an amorphous phase, which is confirmed by an X-ray source of original fibre, shown in Fig. 1 (the chemical composition is given in Table 1) should actively interact in a chemisorbed manner with the cement system, participating in hydration with an increase in volumes and the formation of stronger and more durable products of the reaction. This interaction develops on

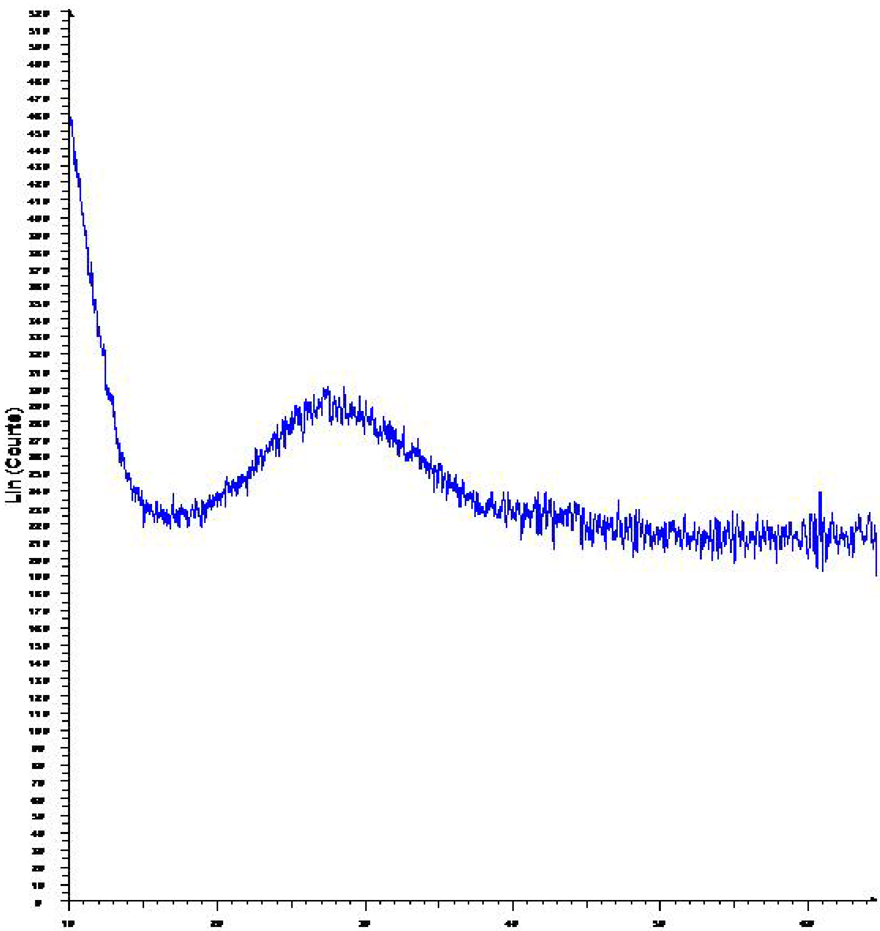

Fig. 1. Basalt fibre diffraction pattern

Table 1. Chemical composition of basalt fibre

Oxide content %								
SiO_2	Al_2O_3	CaO	Fe_2O_3	MgO	Na_2O	K_2O	TiO_2	Total content of other oxides
48.15	16.72	12.66	9.61	4.36	3.84	1.81	1.60	1.25

the surface of the fibre with its general stability in alkaline environment of the cement matrix of a foam concrete;

– Since the development of cracks in non – autoclave foam concretes is getting at a rapid pace, the use of basalt fiber as dispersed reinforcement in these concretes is the most appropriate as it results in their durability and performance characteristics. Fine particles of basalt fibers increase the complexity of the system, contribute to the improvement of foam concrete submicrostructure, which turns from a disordered state into a microhomogeneous one, reducing internal stress and shrinkage of cement stone.

4. Results

Study of basalt fiber using an optical microscope has shown that it has the form of tubular brown fibers, 10 – 20 mm long and 15 – 20 microns thick, hollow, high-gloss, with a smooth surface, corresponding to plagioclase basaltic glass composition with refractive index of 1.5 %. The fibers are resilient; hardness according to the Mohs scale is 4-5.

In Fig. 2 and 3 the diffraction patterns of a control sample of the cement stone and basalt fibre dispersely – reinforced one are shown respectively.

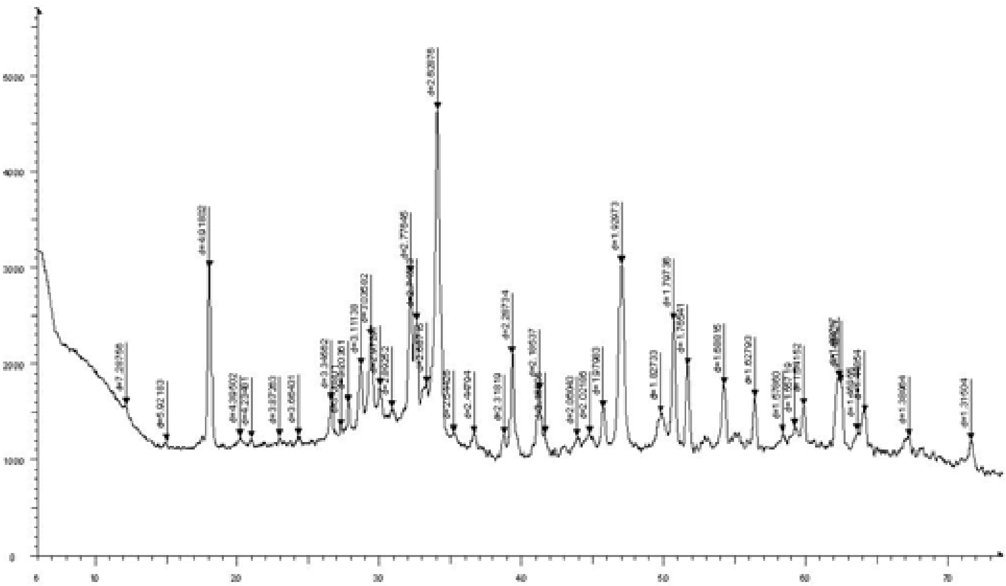

Fig. 2. Cement stone diffraction pattern

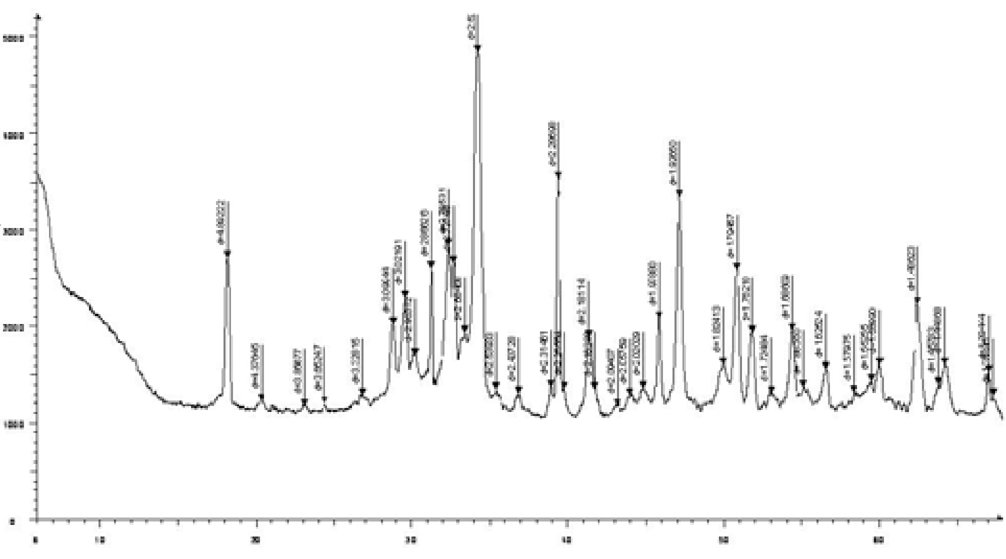

Fig. 3. Basalt fibre reinforced diffraction pattern of cement stone

Comparative analysis of the diffraction patterns of hydration products has shown a number of diffraction reflections corresponding to the following effects: a decrease in the content of calcium hydroxide $Ca (OH)_2$ compared with the corresponding peak in the diffraction pattern of the control sample of cement (d = 4. 89 Å) and increase d = 2. 18 Å, which can be attributed to the presence of calcium hydrosilicates of the general formula CSH (B). In reflection d = 2. 62 Å and d = 1. 48 Å there has been an increase not only in height, but also in the peak area of the diffraction pattern of hydration products of the «cement stone + basalt fiber,» system, which is probably due to the superposition of reflections of $Ca (OH)_2$ and calcium hydrosilicates, which occurs with a simultaneous decrease of the amorphous phase. In addition there appeared significant diffraction reflection d = 2. 28 Å and d = 1. 76 Å, corresponding to quartz [1].

To provide more objective characteristics of the object its microstructure has been investigated and related areas in the direction of the fibers in the cement system were considered.

Figures 4 a and b do not show the sharp edges of tonalities transition ,the light color being mainly dominated; on the surface of the fibers new formations are visible, that testifies to chemisorption fibre interaction with the cement matrix.

The study of the morphology of formations in the dispersely -reinforced basalt fiber cement stone has revealed that the structure is basically represented by fused agglomerates consisting of spherical (5-25 microns) and granular formations of the cement matrix, between which the fibers are arranged, with the formation growths on their surface (Fig. 4). Among them there are thin plates, «leaves» and crystals fused with the cement grains, and are products of the interaction of the surface layer of the basalt fiber and hydration cement system (Fig. 5a and 5b). It should be noted that formations have a higher density than the constituents of the cement stone.

The formations observed are mostly located on the border of the cement stone and basalt fiber, which consists mainly of amorphous silica, which is a proof of chemisorption interaction of the basalt fibre with the cement system (Fig. 5 a and b).

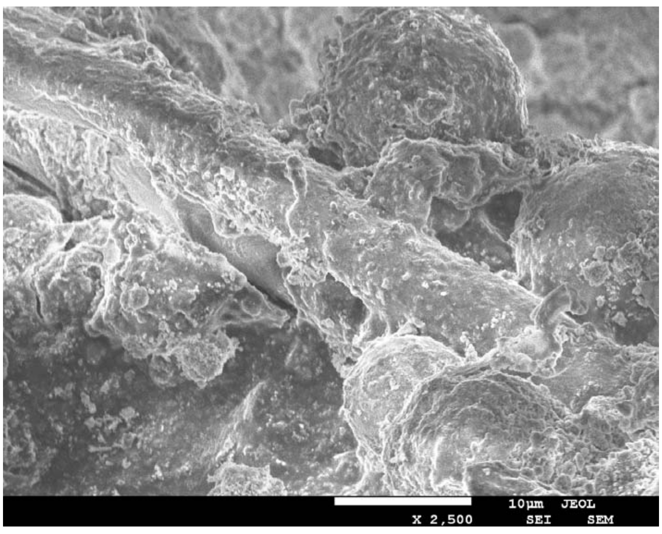

Fig. 4. Scanning electron cement stone microscopy at the age of 36 months, dispersely – reinforced by basalt fibre

Fig. 5 (a). Scanning electron cement stone microscopy at the age of 36 months, dispersely – reinforced by basalt fibre

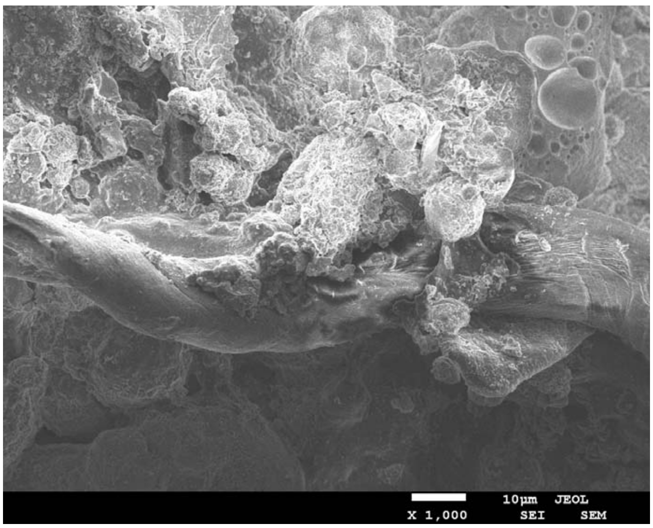

Fig. 5 (b). Scanning electron cement stone microscopy at the age of 36 months, dispersely – reinforced by basalt fibre

On the basis of these data we suggested that the interaction of fibre with the cement system should take place only in the surface layer while maintaining the integrity of the basalt fiber over time. Obviously, the basicity of hydrosilicates on the «fiber-cement stone» phase boundary is reduced and, consequently, the durability of fibre in the cement matrix and the system as a whole increases.

5. Discussion

It is noteworthy to say that a clearly visible effect of the fibre»fullness» in its end parts should be paid attention to (Fig. 6). Since the fibers have a hollow structure with an outer diameter of 10 ÷ 15 mkm and a length of 12-18 mm, thus providing a thin long pore, it can be assumed that the hydration cement products penetrate the end portion to form crystalline growths reinforcing the system, as represented in Fig. 6.

According to V.V. Timashev [2], an active amorphous silicic acid introduced into the cement, contributes to the development of the finest plates, «leaves» on the surface of the cement grains. Plate crystals of such shape and size are observed only in the amorphous silica system. Something like that is developing in the «basalt fiber-cement stone» (Fig. 7). In composition, they are probably amorphous hydrosilicates of low basicity of calcium, type of tobermorit gel, formed in the areas of

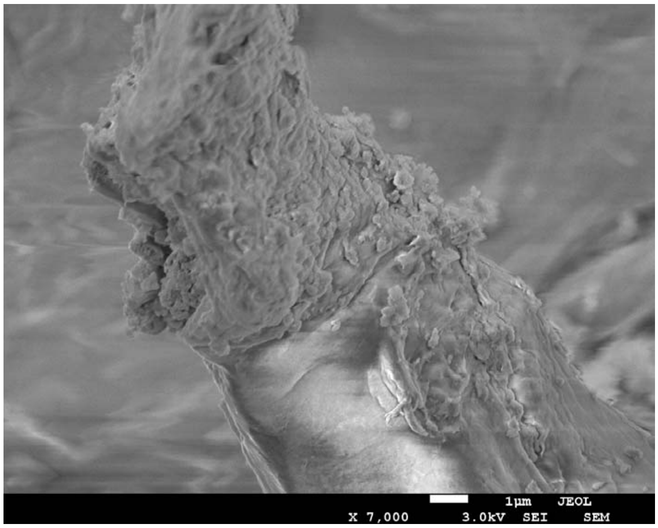

Fig. 6. Scanning electron cement stone microscopy at the age of 36 months, dispersely – reinforced by basalt fibre

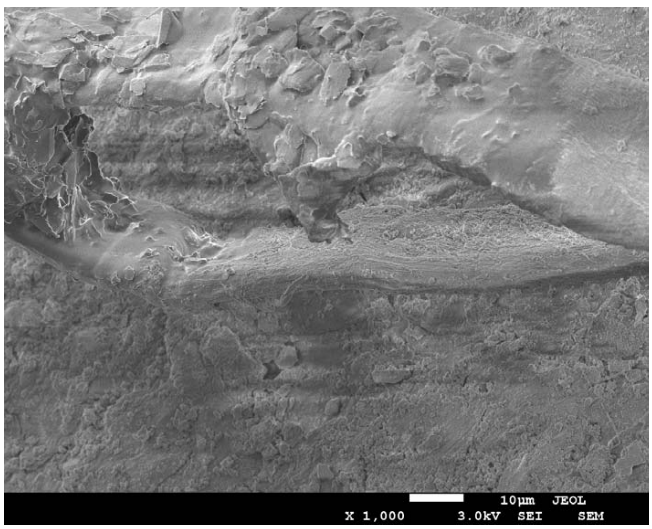

Fig. 7. Scanning electron cement stone microscopy at the age of 36 months, dispersely – reinforced by basalt fibre

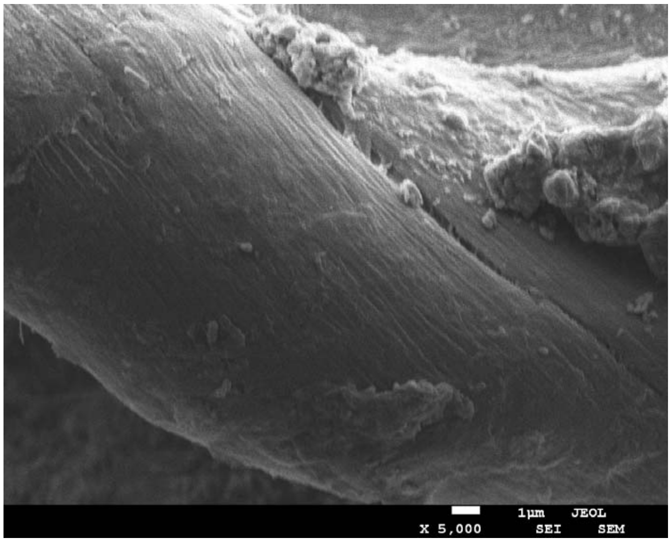

Fig. 8. Scanning electron cement stone microscopy at the age of 36 months, dispersely – reinforced by basalt fibre

Table 2. Physical and mechanical properties of basalt fibre dispersely – reinforced foam concretes

Properties	Numerical results	
	Foam concrete	Fiber foam concrete
Compression strength, MPa	3.34	4.53
Tensile strength in bending, MPa	1.63	2.31
Frost resistance, cycles	35	75
Drying shrinkage, mm/m	3.18	1.37
Heat conduction, W/(m °C)	0.182	0.176

solution supersaturated by Si^{4+} ions. The number of such crystals and gelatinous mass increases with increasing silica content, and the number of crystals of calcium hydroxide and calcium carbonate is reduced.

Perhaps, in fiber surface areas in the places of mechanical defects crystallization centers are created (Fig. 7 and 8), further increasing the effect of the dispersed fiber as reinforcement. To break the foam, which has a similar structure, you need to make great efforts. Thus, strength increases, particularly under bending and accordingly durability of cement foam concrete (Table 2).

6. Conclusions

The research of new formations structure has revealed that they form a gel-like spatially connected carcass which is further enhanced by reinforcing effect of the fibers, which provides high strength characteristics of materials. This gel structure is characterized by a large stress relaxation and, therefore, a great opportunity for plastic deformation, and thus increased fracture resistance, which is especially important in the manufacture of foam concretes of non-autoclave curing [3].

Such a structure, where micro cracks develop slowly as a result of their blocking in the process of plastic deformation of foam concrete will provide superior performance, good frost resistance and durability, which has been confirmed by the test results (Table 2).

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