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Peculiarities of Structure Formation in System "Cement – Basaltic Fibre"

Nelubova V.V.
Belgorod state technological university
named after V. G. Shukhov
Belgorod, Russian Federation
vvnelubova@gmail.com

Babaev V.B.
Belgorod state technological university
named after V. G. Shukhov
Belgorod, Russian Federation
sphinx-sx@mail.ru

Popov A.L.
Belgorod state technological university
named after V. G. Shukhov
Belgorod, Russian Federation
surrukin@gmail.com

Bezrodnyh A.A.
Belgorod state technological university
named after V. G. Shukhov
Belgorod, Russian Federation
andron93@list.ru

Abstract - **The article deals with the main peculiarities of phase- and structure formation in the system "cement-basaltic-fiber" with the use of initial and heat treated basaltic fiber. The authors used heat-treated fiber by the authors' method suggested earlier, which provide its recrystallization. As the result, the surface layer is solidified with the changes in the fiber structure: there is no corroding dissipation after exposing in hardening cement. Primary formations are crystallized on the fiber surface with good adhesion to it. It is proved that the presence of basaltic fiber in cement does not influence the hydration process, but heat-treated fiber has better adhesion than the initial fiber thanks to the developed surface and chemical relation with the cement system.**

Keywords— basaltic-fiber, heat-treated basaltic fiber, mineral fiber, alkali resistance

I. Introduction

With the development of construction, requirements for building materials become more severe in order to fulfill more complex engineering solutions. The main requirements are imposed on physical-mechanical properties of concrete and its fragility. Thus, the concrete matrix has lower bending tensile strength and is apt to microcracks formation. Modern research is aimed at improving physical-mechanic characteristics of materials by introducing mineral modifiers and additives of different composition and nature [1–9]. However, hardening the base cement matrix by additives does not allow increasing composite bending strength. The effective way of improving concrete quality in this case is strengthening with different fibers, including dispersed fiber [10–17]. Perspective materials are concretes micro-strengthened with basaltic fiber. Basaltic fiber has high tearing resistance and elasticity module, which it can transmit to concrete matrix. But the research shows its low alkaline endurance in hydrating cement rock, which reduces dramatically basaltic fiber characteristics due to its solution.

Together with colleagues from MSU named after M.V. Lomonosov, the authors suggest the way of improving basaltic fiber alkaline endurance [18–20], which was modified taking into account raw materials specification, in particular, structural-topological specifications of basaltic fiber of different manufacturers. It has been proved that the most effective way is fiber heat-treatment at temperature of 500 °C with further cooling (hardening) under normal conditions at 25 °C. This modification improves fiber physical properties, in particular, improves its resistance over a long period of time in the hardening cement with high alkaline endurance. It happens due to fiber surface recrystallization at high-temperature oxidation that results in the formation of the protective layer based on the aluminum-silicon-oxygen grid of high degree of binding.

Fiber action efficiency in the cement matrix is provided by both the qualities of the fiber itself (high deformational characteristics) and adhesive interaction of the concrete system components. It is evident that fiber modification can result in lowering consolidated composite connection. That is why, it is important to study peculiarities of structure formation in the system "cement-basaltic fiber" to estimate the influence of heat-treated fiber on hydrational phase-formation and forecasting its durability and lasting effective operation in the cement rock.

II. Methods and materials

In the experiment, Portland cement CEM I 42,5 H made by PLC "Belgorod cement", basaltic fiber by PLC "MAchzavod BASK" and heat-treated basaltic fiber according to the suggested method were used.

The influence of alkaline medium was studied using the basaltic fiber microstructure in the model system of cement hydration in natural conditions during 28 days and nights. Cement slurry was used as a corroding medium with alkaline condition pH=12.9. Decarbonized distilled water and cement were used to prepare the solution. Fluff basaltic fiber was added to the solution, whose concentration was 7 % of the cementing mass.

To estimate the influence of heat-treated basaltic fiber on hydration processes in cement system composite, samples aged 28 days and nights and micro hardened with raw and heat-treated fiber were used. To provide precise detecting of possible neo-formations in the system “cement-basaltic fiber”, the amount of fiber was increased and was 12% of cementing mass.

Estimation of alkaline medium influence on the basaltic fiber microstructure and peculiarities of cement rock structure formation was done with the help of scanning electron microscopy and X-ray fluorescence analysis in the high-technology center of Belgorod State Technological University named after V. G. Shukhov.

X-ray fluorescence analysis was done at X-ray operating station ARL 9900. The samples were prepared by grinding in agate mortar in the alcohol medium. Scanning electron microscopy was done with a highly precision microscope TESCAN MIRA 3 LMU.

III. Results

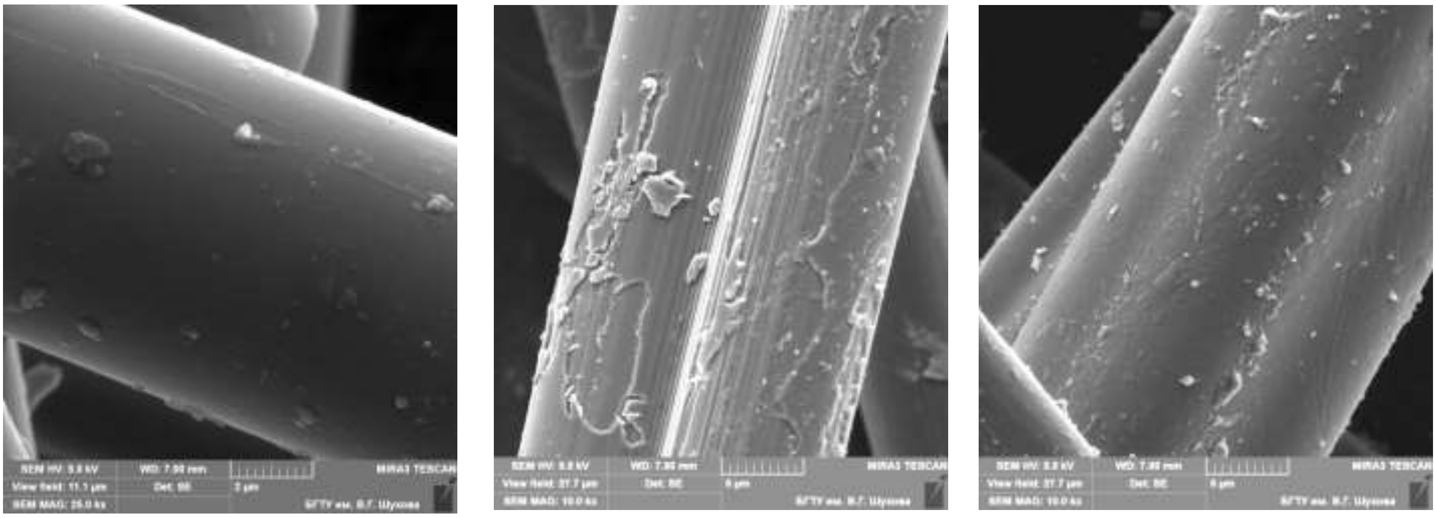
According to the results of micro structural investigations of basaltic fibers (Fig. 1), it is seen that the initial basaltic fiber surface is smooth, but local globular new formations can be recognized. These are presumably carbonatization products of 1 mkm in size, which, as well as fiber surface roughness, are smoothly distributed along the entire fiber.

Influence of the aggressive alkaline medium on basaltic fiber before heat treatment is vivid. The samples had severely corroded parts in the form of longitudal “trenches” along fiber extension that evidences about an anisotropic fiber structure (Fig. 1, c, d). Here the fiber breaks along the boundary of aluminium-silicate fiber ply. The affected area has distinct boundaries (Fig. 1, c) and leaching depth up to 400 nm (Fig. 1, d). As the result of corrosion formation along the whole fiber length, real destruction is probably bigger. Also, globular neo-formations are identified which can be treated as both X-ray amorphous calcium carbonate and alkali reaction products with basaltic fiber material.

Heat-treated basaltic fiber demonstrated opposite results (Fig. 1, e, f). Most of the surface is covered with globular new formation, but there is no vivid alkali corrosion. The diameter of new formations varies in size from 100 nm up to 3–4 mkm and they are probably products of an acid-base agent interaction ($Ca(OH)_2$) with the fiber glass phase. Such numerous new formations and their smooth distribution on the fiber surface can indicate fiber activity increase in relation to cement hydration products and can prove that heat-treated fiber has better adhesion to cement rock than initial basaltic fiber.

Hence, absence of corroded areas in the form of longitudal “trenches” and other serious morphological changes on the fiber surface evidences high resistance of heat-treated fiber to aggressive alkaline medium. Nevertheless, formation of new crystals concreted to the fiber surface allows suggest good adhesion of calcium silicate hydrate formed as the result of cement hydration to modified fiber.

X-ray pattern analysis (Fig. 2) of cement rock samples with the initial and heat-treated fiber and cement rocks without fiber did not show changes in Portlandite minerals contents such as the alite hydration indicator and possible puzzolanic reaction and other significant differences between profiles. Therefore, basing on X-ray phase analysis, basaltic fiber does not have significant influence on hydrational processes in the cement system.



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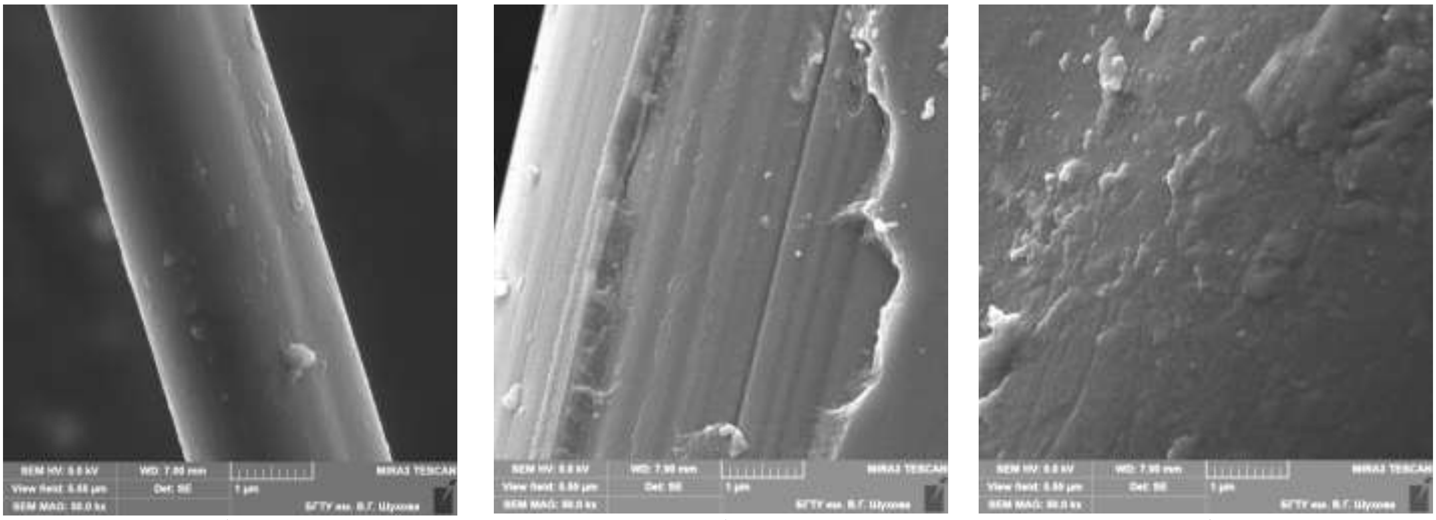


b d f

Fig. 1. Influence of the alkaline medium for the model system on the basaltic fiber microstructure: a, b – initial state of the fiber, c, d – influence of the alkaline medium on the fiber before heat treatment, e, f - influence of the alkaline medium on the fiber after heat treatment.

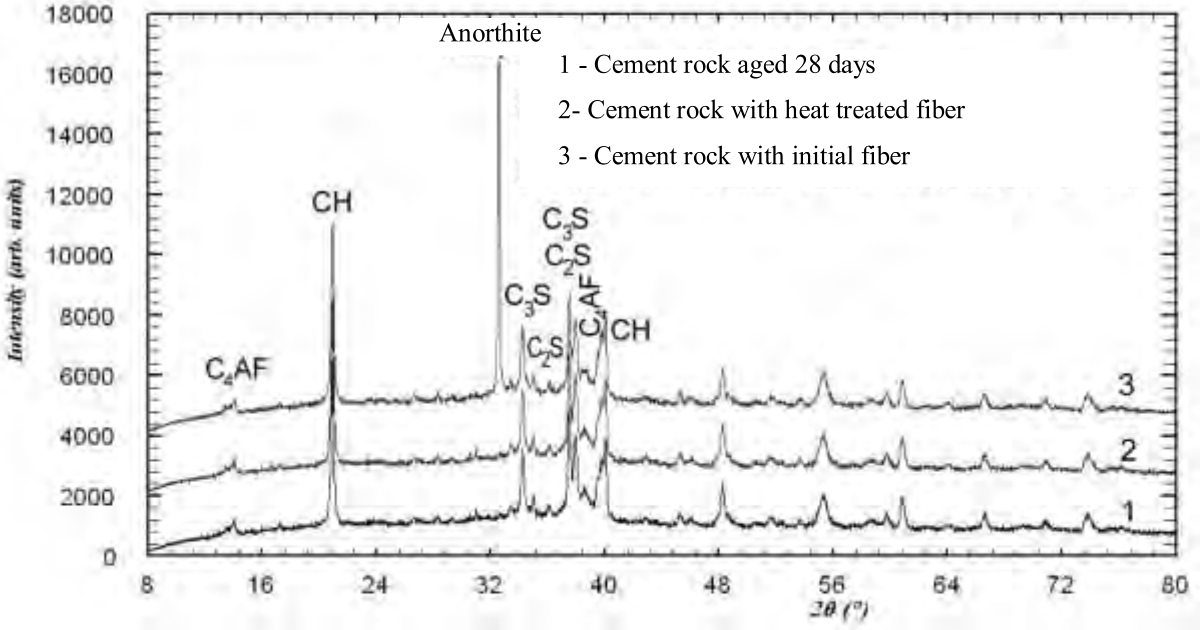
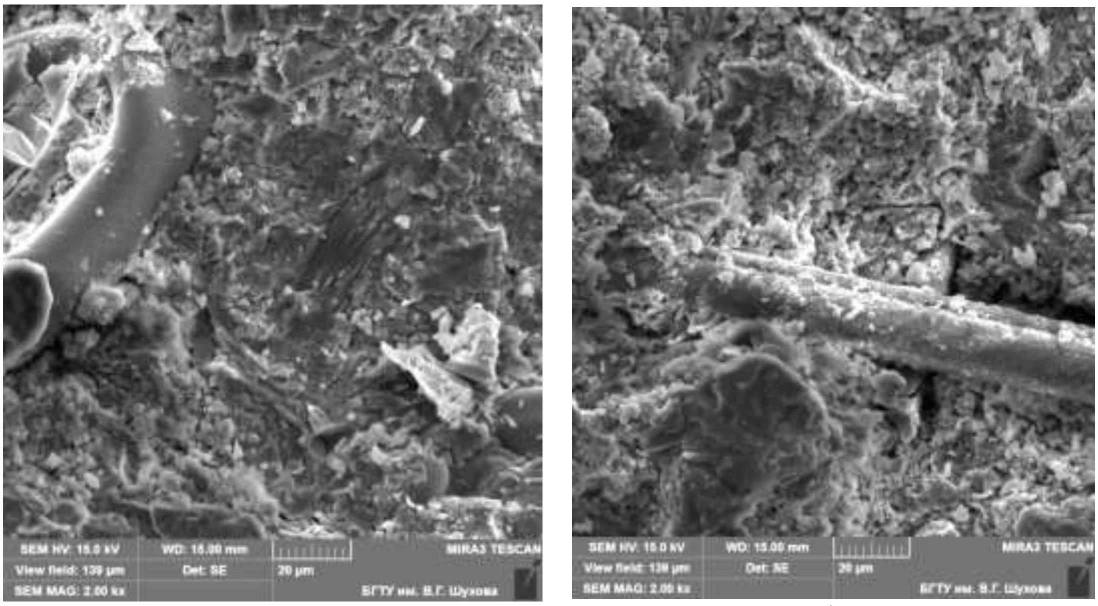


Fig. 2. X-ray pattern of the cement rock of the initial composition (1) with basatic fiber before (3) and after (2) heat treatment.

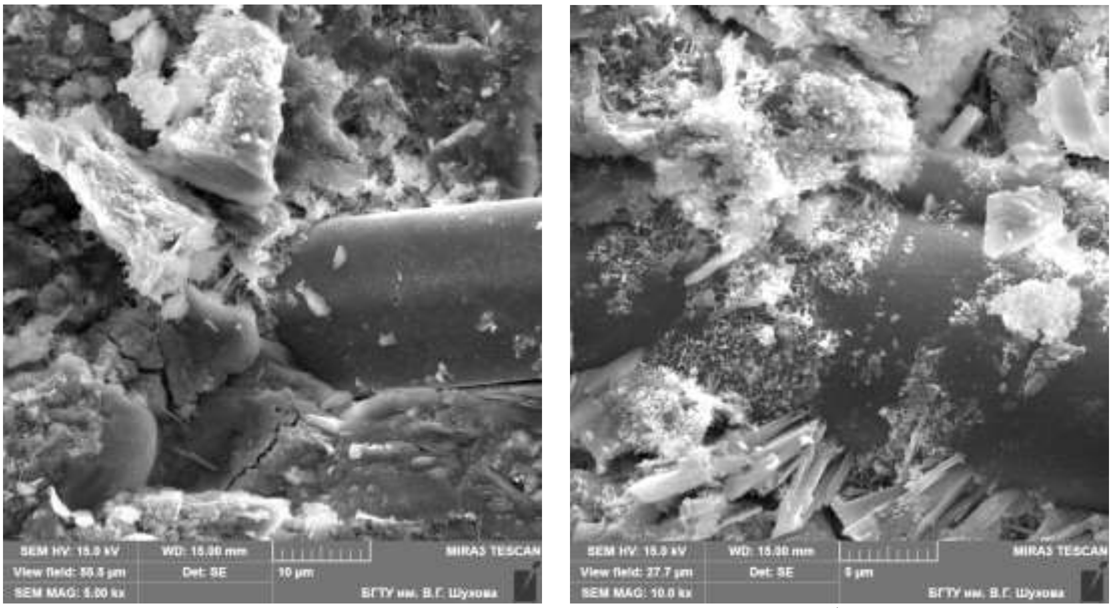
The results of electron microscopy showed that cement rock morphology with initial and heat-treated basaltic fiber does not change, preserving the dense and homogenous structure without severe defects (Fig. 3, a, b). But the external view of the fiber evidences its activity in the hydration products of the cement minerals and the degree of their interaction. In the cement rocks samples with initial basaltic fiber, the fiber surface is smooth; covering with new formations is minimal (Fig. 3, a). The samples with heat-treated fiber differ radically. Nearly the entire surface is covered with new formations (Fig. 3, b), which can be treated as both hydrated cement new formations and hydration products as the result of cement mineral interaction with active centers of modified aluminosilicate material. It is the result of fiber surface activity or, to be exact, a greater number of Broensted acidic sites on it, where acid-base interaction of cement minerals hydration products with reactive adsorptive center takes place. It provides better adhesion of heat-treated fiber to cement new-formations in comparison with the initial one. This fact is proved when studying the contact zone between cement rock and basaltic fiber (Fig. 4, a, b).

The new formation character does not depend on the fiber type and is introduced by globular phases, probably amorphous (Fig. 4, a, b). It is probable that these phases are the result of the described acid-base interaction.



a b

Fig. 3. Cement rock microstructure at the age of 28 days, harderned with basaltic fiber: a – initial; b – modified.



a b

Fig. 4. Contact zone between new formations and basaltic fiber in the cement rock structure of 28 days old: a – initial; b – heat-treated.

Hence, active acid centers on the surface of basaltic heat-treated fiber, able to interact with base hydration products of cement minerals, can be centers of new formation crystallization centers that proves high adhesion of cementing hydration products to the heat-treated fiber, the number of adsorption centers on which exceeds initial basaltic fiber.

IV. Conclusion

Thus, the main peculiarities of structure formation in the system "cement-basaltic fiber" with initial and heat–treated basaltic fiber have been studied. Alkaline endurance of heat-treated fiber has been shown. Basing on X-ray phase analysis, heat-treated fiber does not influence cement hydration as there are no changes in Portlandite contents such as the alite hydration indicator, possible puzzolanic reactions, and other significant differences between profiles.

The new formation grid on the fiber surface, which according to morphology and sizes has a crypto-crystalline structure is explained by formation of Si–OH-links in the surface layer. Heat-treated fiber is a base for new formations, appearing duirng cement hydration and has higher adhesion than non-treated fiber due to the developed surface and chemical affinity with the cement system. Thus the coating on the fiber surface of new formations with globular phases prevents further fiber interaction with cement rock active components during utilization, which makes heat-treated fiber more alkaline resistant in comparison with initial basaltic fiber.

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