STEEL FIBER CONCRETE: THE COMPOSITE MATERIAL IN HIGHWAY ENGINEERING UNDER THE ALTAI REGION CONTINENTAL CLIMATE CONDITIONS

Klara V. Talantova[1], Nikolai M. Mikheev[2], Sergei V. Tolstenev,[3] Leonid A. Chvoinski[3]
[1]Altai State Technical University, 46, Lenina St., Barnaul. 656099, RUSSIA
FAX: 385 226 0516, E-mail: user@oasis.secna.ru
[2]Barnaul Building College, 68, Lenina St., Barnaul, 656015, RUSSIA
[3]AltaiAvtoDor, 105, Papanincev St., Barnaul, 656099, RUSSIA

SUMMARY: The climatic zone of Altai Region can be referred to as sharply continental, with the absolute air temperature maximum of +36.7˚C (309.7 K) and the absolute minimum of -51.5˚C (221.5 K). To constructions of highway engineering in Altai Region, requirements for high reliability and durability are set. They can be effectively met through the use of steel fiber concrete (SFC). SFC is a composite material which has better physical and mechanical properties compared to the traditional concrete and ferroconcrete. Conducted by Russian and foreign scientists, research work on the properties of SFC, as well as results of the authors' experimental and theoretical research on the SFC atmospheric resistance have led to the conclusion that it is expedient to use SFC in the constructions for highway engineering. Laboratory research, experimental construction of installations in Altai Region and their operation for over 15 years testify high technical and economic efficiency of SFC application in highway engineering.

KEYWORDS: steel fiber, concrete jig, steel fiber concrete, sharply continental climate, constructions for highway engineering, atmospheric resistance, durability, technical economic efficiency.

INTRODUCTION TO THE PROBLEM

The climatic conditions of Altai Region are sharply continental with hot summers and long rigorous winters. The analysis of long standing observation shows that the principal factors to influence the construction elements used in the atmospheric conditions of Altai Region are big temperature differences in the humid environment [1]. Besides strength and stiffness, such enhanced requirements as resistance to frost, corrosion, and atmospheric media are set for the constructions of pavements, bridges' parts, by-road waterway flumes, etc. used under such conditions.

These requirements are met by such composite material as Steel Fiber Concrete (SFC). As other composite materials, SFC, provided necessary rules of forming its structure are followed, has the properties considerably surpassing the sum of its components' properties.
That is, increased reliability and durability of the construction parts for highway engineering may be ensured through the use of steel fiber concrete - construction composite received through reinforcement of a frail concrete jig with slender steel fibers. The fibers can be made from wire, a sheet, a slab, a melt, etc. The passed area of fiber reinforcement is determined by

the following parameters: diameter of a fiber (d_f) – 0.3 ÷ 1.2 mm, ratio of length and diameter (l_f/d_f) – 50 ÷ 125, reinforcement percent by volume (μ_f) – 0.5÷3.0 %.

EXPERIMENTAL - THEORETICAL PREMISE

As researches [2,6] have showed, the structure of the concrete jig in SFC, compared to the average concrete, is characterized by a smaller quantity of big pores and capillaries, presence of small closed pores and bigger homogeneity (Fig. 1). At that, there happens an increased size of the contact zones with improved properties near the fibers' surface (300 mkm on the average) compared to the analogous contact zones (50÷60 mkm on the average) beside the aggregate. Formation of such contact zones is a result of the adsorption thickening of the new hydration formation under the influence of the molecular field of forces [6]. Moreover, when loading the construction elements, metallic fiber, arbitrarily arranged in the cross-section of the element, is redistributing the stress gradients, thus smoothing over and reducing their concentration. In case the structure of SFC has a micro defect, its development is averted or slowed down by the dispersely arranged fibers.

The researches of the SFC frost-resistance [5,7] and the researches of resistance to attack by corrosive media [2] showed that, depending on the parameters of fiber reinforcement, kind and brand of the concrete jig, these characteristics are 2 and more times as large as those of traditional concrete and ferroconcrete.

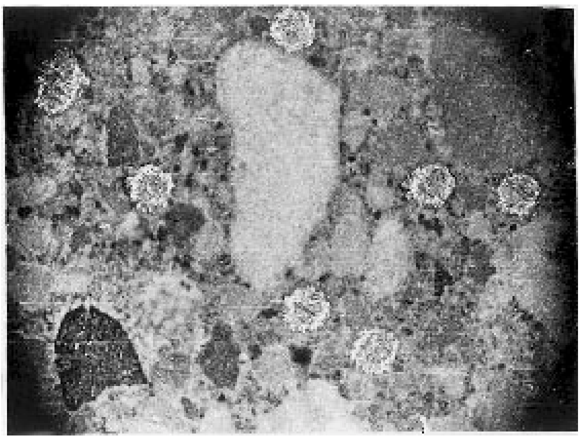
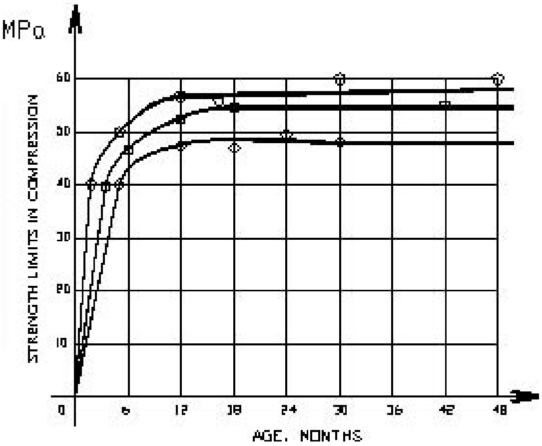


Fig. 1 Microphotograph of Steel Fiber Concrete by x20 enlargement

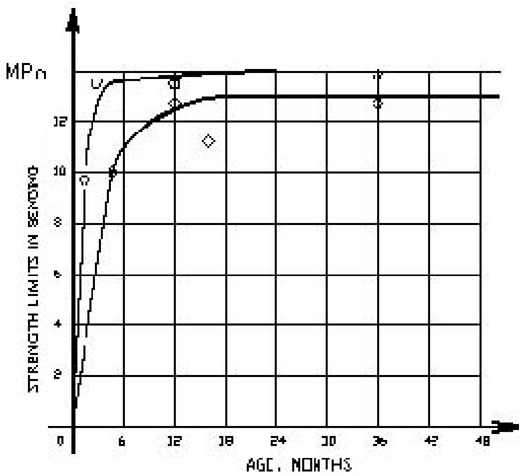
Experimental check of resistance to attack by atmosphere of the SFC under the conditions of continental climate of Altai Region, was carried out by the AltSTU roof-station (Barnaul), where the laboratory specimens under natural conditions experienced in turn freezing and thawing (in spring-autumn periods), subzero temperatures and above-zero temperatures, and were exposed to wind, rain, snow, and solar radiation. The exposed specimens were kept at the roof-station from 28 days to 48 months. Laboratory specimens were made of specially designed Steel Fiber Concrete mixtures [3]. The same method was used to design pilot SFC constructions.

The results of strength tests (Fig. 2), and also careful visual inspection confirmed high resistance to attack by atmosphere, which may also happen under Altai region's atmospheric conditions. Moreover, as charts show, strength characteristics of SFC specimens exposed to tests, compared to characteristics of in 28-days age, have not reduced, but grown 2 or 3 times on the average. Fiber corrosion inside the specimens was not observed. Obtained results are well comparable to data obtained by other researches [4,7].

a)



b)



c)

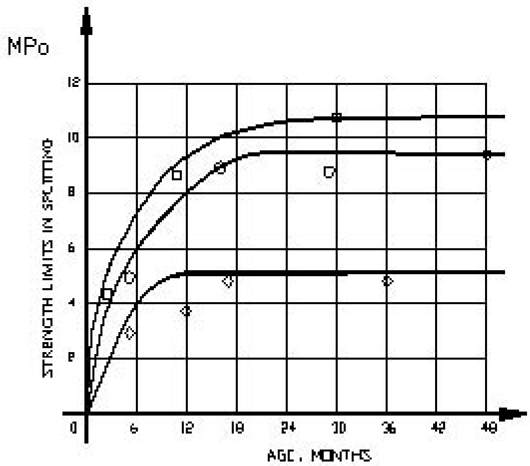


Fig. 2 Experimental relationship of strength characteristics of SFC exposed to atmospheric influence as a function of specimens' age

a) in compression; b) in bending; c) in splitting

O - *Prisms 10x10x40 cm;* d_f*=0,3 mm,* l_f*=30 mm,* $\mu_{f,v}$*=1,5%*

- *Cubes 15x15x15 cm;* d_f*=0,5 mm,* l_f*=60 mm,* $\mu_{f,v}$*=1,75%*

◊ - *Prisms 4x4x16 cm;* d_f*=0,5 mm,* l_f*=60 mm,* $\mu_{f,v}$*=1,75%*

In the design of concrete and ferroconcrete construction parts, and for the highway construction as well, rather high reliability indices are used on materials. It is known to be connected with rather essential statistic variability of both concrete's and ferroconcrete's strengths. According to the Russian Construction Codes, normal coefficient for the variation of concrete's strength characteristics is 0.135. Large volume of experimental researches of SFC showed high stability of its strength characteristics. For SFC, the coefficient of variation is estimated as 0.06-0.09. That is, statistic variability of the SFC composite's properties is significantly lower, which allows to guarantee reasonable redundancy of material's properties in design, having reduced the reliability coefficients.

EXPERIENCE OF PRACTICAL APPLICATION

All above stated lay the foundation for the development and field tests of constructions with the use of SFC for highway engineering in Altai region, including the construction of road surfacing and construction elements of frameworks for a motor-road bridge, road surfacing for automobile road of the second engineering category, near-road waterways, etc. Designing experimental elements, the authors considered the equal strength provision for both the experimental construction elements with the use of the SFC and the standard ones.

In the road pavement of a bridge instead of cement covering, two layers of water proofing, a layer of cement-concrete (B30) with a welded metal mesh and two layers of asphalt concrete (total thickness of 0.2 m), two layers were confirmed by the standard design – steel fiber concrete and water proofing (total thickness 0.1 m). This decision reduced the labor input by 15.5%, specific consumption of materials by 48%, and cost by 21%, while providing the designed durability, which, besides the above mentioned parameters, is determining by the increased water proof and wear resistance. The exploitation of the SFC road pavement of a bridge across the Povalikha River during 17 years under the rural conditions confirmed the correctness of the chosen premises.

a) b)

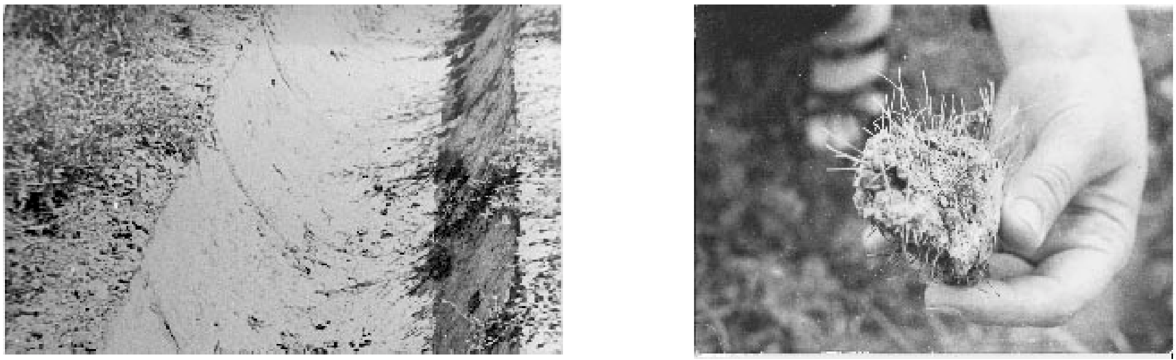


Fig. 3 Experimental part of the steel fiber concrete waterway flume at the drive-in to village Ovchinikovo

a) General view;

b) Fragment of Steel Fiber Concrete have been received from the operated waterway flume (the inside fiber corrosion is not observed)

The same conclusion may be drawn from the 15-year use of the by-road waterway flume, set up at the drive-in to village Ovchinikovo (Fig. 3). The built-up element of flume has the shape of an empty half-cone with wall thickness of 0.02 m. The use of SFC in the flume's construction allowed to reduce the volume per one running meter from 0.3 m^3 to 0.05 m^3, that is six times. Condition checks on the flume during the whole period of its use showed high resistance to corrosive media and general work stability.

The highway bridge framework beams (T-image cross-section) were designed to be made of steel fiber ferroconcrete. Having saved a part of the longitudinal principal reinforcement, this allowed to substitute all meshes and cages by fiber reinforcement. This decision made it possible to enlarge the beam, having reduced the height of cross-section of a flange and a rib of a beam, and to increase width of the beam. As a result, with the guarantee of the required strength, deformability, reliability and durability, the designed reduction of the labor input to produce the beam comprised about 40%, while in erecting the framework construction it comprised about 16.8%. The decrease in the cost of the framework of the bridge is equal to 19%. Improvement of the bridge framework structure by the application of SFC requires further experimental checking.

a) b)

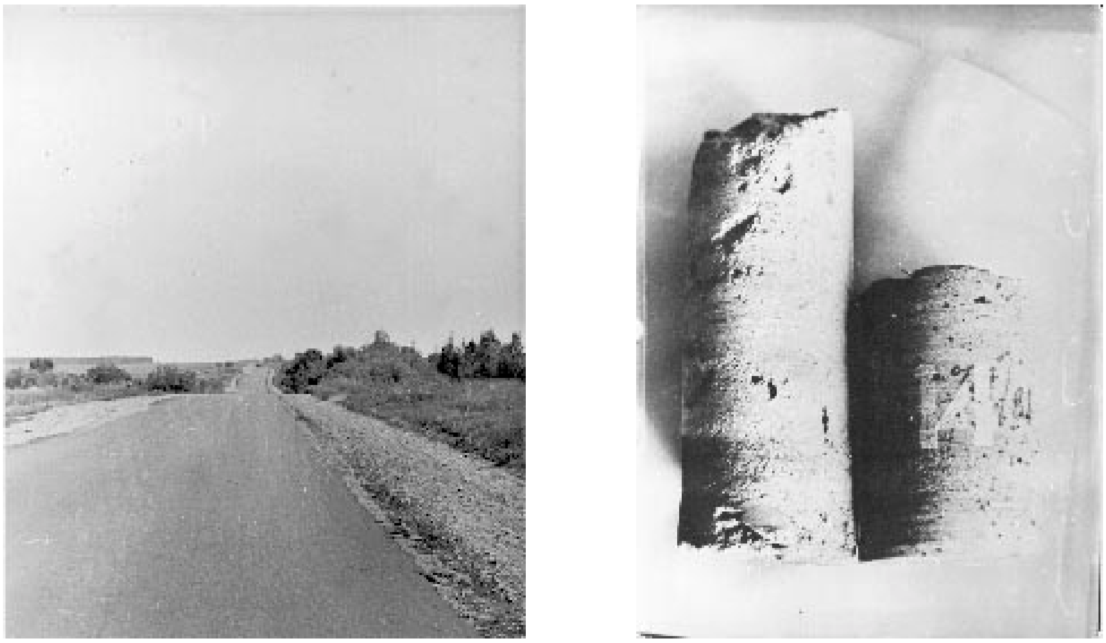


Fig. 4 Experimental part of hard steel fiber concrete base of the Barnaul-Biisk highway

a) General view;
b) Cores taken from the standard base of the road (h=200 mm; left) and the steel fiber concrete base of the road (h=120 mm; right)

The 17-year experimental use of the SFC-construction of base of the second engineering category Barnaul–Biisk road (Fig. 4) showed that it is possible to ensure the designed strength and deformation characteristics of material, high abrasion resistance, impact strength, resistance to attack by atmosphere and reduce specific consumption of materials by 40% and cost by 14.4 %. Application of SFC in the road pavement results in approximately the same data.

CONCLUSION

The above stated shows that steel fiber concrete as the construction composite material ensures high reliability, durability of construction for highway engineering under the continental climate of Altai Region's conditions. Under the most unfavorable conditions of construction and use, SFC is more effective than standard concrete and ferroconcrete.

REFERENCES

1. Gorbunova T.A. “Characteristic of Rock Brands of Barnaul, as Base to the Engineering-Geology Zoning of its Territory”. Dissertation Abstract. Moscow, 1975, 17 p.
2. Gulimova E.V. “Research of the Corrosion Resistance of Reinforcement in Steel Fiber Concrete”. Dissertation Abstract. Leningrad, 1979, 16 p.
3. Talantova K. V. “About Steel Fiber Concrete Mixture Design Procedure”., in *Actual Problems of Construction Material Study* , Tomsk, 1998.- p.p. 69-71
4. Colin D. Johnston. “Steel Fibre - Reinforced Concrete – Present and Future in Engineering Construction”. *Composites*. 1982, vol. 13, #2, p.p. 113-121.
5. AQUILA STEEL COMPANY LIMITED.: “Technical Manual : Fibrecrete Properties, Pavement Design”; Revesby, NSW 2212, Australia, 1983.
6. Lobanov I.A. “The Basics of the Disperse Enforced Concrete (Fiber Concrete)”. Dissertation Abstract. Leningrad, 1982.
7. Kurbatov L.G., Ermilov U.I. “Steel Fiber Concrete Constructions in Building”. *Overview Information*, #8. Moscow, 1983, p.58
8. Talantova K.V., Tolstenev S.V., Mikheev N.M. “Experience in Use of Steel Fiber Concrete for Highway Engineering”. In: *Use of Fiber Concrete in Construction*. Leningrad, 1985, p.p. 47–50.
9. Talantova K.V., Mikheev N.M. “Summary on the Performance of Steel Fiber Constructions for Highway Engineering”. In: *Technology of Manufacture and Qualities of New Composite Building Materials*. Leningrad, 1986, p.p. 35–40.
10. Talantova K.V. “Study on the Reinforcement–Concrete Contact Zone by Means of Micro Stiffness”. In: *Composite Materials in Russia's Economy*. Barnaul, 1997, p.p. 57–59.