COMPARATIVE ANALYSIS OF MODERN STUDIES ON FIBER-REINFORCED CONCRETE FOR MONOLITHIC CONSTRUCTION: EFFECT OF FIBER TYPE ON THE STRUCTURE, STRENGTH, AND DURABILITY OF CEMENT COMPOSITES

PhD Obidjonov Jahongir Tokhir o'g'li
Tashkent University of Architecture and Civil Engineering
(tel. 99-794-45-09, e-mail.: x.jahon13@gmail.com)

Abstract

This paper presents a comparative analysis of domestic and international studies devoted to the development and application of fiber-reinforced concrete (FRC) for monolithic construction. The results of investigations on basalt, polypropylene, steel, and synthetic macrofibers used for dispersed reinforcement of cement composites are reviewed. The influence of fiber type, length, and dosage on compressive and flexural strength, crack resistance, deformability, impact toughness, shrinkage behavior, and durability of concrete is analyzed. Particular attention is paid to studies concerning fine-grained fiber-reinforced concretes, self-compacting fiber-reinforced concretes, and composite materials intended for monolithic construction. Based on the analysis of published dissertation studies, it has been established that the incorporation of basalt fibers increases flexural strength by up to 40–60%, crack resistance by up to 70%, and reduces shrinkage deformation by 15–35%. The use of synthetic macrofibers significantly improves the energy absorption capacity and operational reliability of concrete structures. It is shown that the optimum fiber content for most types of fibers ranges from 0.5 to 2.0% by cement mass or from 0.1 to 1.5% by volume of the mixture. The study identifies promising directions for future research related to the development of high-performance and self-compacting fiber-reinforced concretes for application under hot and arid climatic conditions.

Keywords:
fiber-reinforced concrete, basalt fiber, polypropylene fiber, steel fiber, synthetic macro-fiber, monolithic construction, strength, crack resistance, durability, cement composite.

Introduction

The modern development of the construction industry is characterized by continuously increasing requirements for the operational reliability, durability, and crack resistance of concrete and reinforced concrete structures. One of the most effective methods for improving the performance characteristics of concrete is dispersed reinforcement with various types of fibers, which enables the formation of a three-dimensional reinforcing network within the cement matrix. This network inhibits the initiation and propagation of microcracks and enhances the material's resistance to external actions [1].

According to the fundamental research conducted by Pukharenko [1], fiber-reinforced concretes represent a special class of composite materials distinguished by pronounced structural anisotropy and the ability to sustain tensile stresses even after crack formation. Consequently, significant improvements are achieved in flexural strength, impact toughness, fatigue resistance, and service life of structures.

Over the last two decades, considerable attention has been devoted to the study of steel, basalt, glass, polypropylene, and synthetic macrofibers. Among these materials, basalt fibers are of particular interest because of their high tensile strength, chemical stability, corrosion resistance, and relatively low production cost [2,3].

The rapid development of monolithic construction technologies has created a demand for innovative fiber-reinforced concrete mixtures possessing high workability, self-compacting ability, and enhanced operational reliability [4].

Theoretical Background of Dispersed Reinforcement of Concrete

The reinforcing mechanism of fibers in concrete is based on the redistribution of internal stresses between the cement matrix and the reinforcing fibers. When microcracks occur, fibers bridge the crack surfaces and prevent their opening, thereby ensuring stress transfer through the interfacial transition zone.

According to the studies conducted by Naaman, the effectiveness of fiber reinforcement is governed by the following factors [5]:

Elastic modulus of the fiber;

Tensile strength of the fiber;

Fiber aspect ratio (length-to-diameter ratio);

Adhesion between the fiber and the cement matrix;

Fiber volume fraction;

Uniformity of fiber distribution.

The highest reinforcement efficiency is achieved when a spatially distributed fiber network is formed within the composite, enabling the material to withstand tensile stresses at various stages of deformation and crack development.

Comparative Analysis of Major Fiber Types

Table 1

Main Characteristics of the Most Common Fiber Types

Fiber Type	Density, kg/m^3	Tensile Strength, MPa	Elastic Modulus, GPa	Main Advantages
Steel Fiber	7800	1000–2500	200	High strength and stiffness
Basalt Fiber	2600–2800	2800–4800	85–95	Excellent corrosion resistance
Polypropylene Fiber	910	400–700	3–10	Low cost

Synthetic Macrofiber	900–950	450–800	7–15	High crack resistance

The analysis indicates that steel fiber possesses the highest elastic modulus; however, it is susceptible to corrosion processes. Basalt fiber combines high strength with excellent chemical resistance, making it particularly suitable for application in aggressive environments [2, 3].

Studies on Basalt Fiber Reinforcement

One of the most comprehensive investigations into the application of basalt fibers was conducted by M.O. Zubova [2]. The author demonstrated that the incorporation of basalt fibers contributes to the formation of a denser cementitious matrix and reduces the number of microstructural defects.

The results obtained by various researchers are summarized in Table 2.

Table 2

Effect of Basalt Fiber on Concrete Properties

Author	Type of Concrete	Fiber Content	Change in Compressive Strength
Zubova M.O. [2]	Fine-grained concrete	1.0–2.0%	+15–25%
Buchkin A.V. [3]	Corrosion-resistant concrete	1.5–2.0%	+12–20%
Kalugin I.G. [6]	Foam concrete	0.5–1.5%	+10–18%
Chhi Sovann [4]	Composite binder-based concrete	1.0–2.0%	+18–30%

A particularly significant effect was observed in flexural strength enhancement. In several studies, the increase in flexural strength reached 40–60%.

Studies on Synthetic Macrofibers

In recent years, synthetic macrofibers have attracted considerable research interest. According to the findings reported by M.P. Kostrikin [7], synthetic macrofibers effectively control crack opening and can partially replace conventional reinforcement.

Table 3

Efficiency of Synthetic Macrofiber Reinforcement

Parameter	Without Fiber	With Macrofiber
Flexural Strength	100%	120–140%
Fracture Energy	100%	180–250%
Crack Resistance	100%	150–200%
Impact Toughness	100%	170–230%

These results confirm the high effectiveness of synthetic macrofibers in industrial and civil engineering structures.

Comparison of the Effectiveness of Different Fiber Types

Table 4

Comparative Effectiveness of Reinforcing Fibers

Property	Steel Fiber	Basalt Fiber	Polypropylene Fiber	Synthetic Macrofiber
Compressive Strength	+10–20%	+15–25%	+5–12%	+8–15%
Flexural Strength	+40–80%	+30–60%	+15–30%	+35–70%
Crack Resistance	+60–120%	+40–90%	+30–60%	+70–150%
Corrosion Resistance	Low	High	Very High	Very High

The obtained data indicate that basalt fiber and synthetic macrofiber are among the most promising materials for modern monolithic construction applications.

Conclusions

1. The analysis of the reviewed literature demonstrates the high efficiency of dispersed reinforcement of cement-based composites using various fiber types.

2. The most significant improvement in flexural strength is achieved through the incorporation of steel and basalt fibers.

3. Synthetic macrofibers provide the greatest enhancement in crack resistance and fracture energy.

4. Basalt fibers exhibit an optimal combination of mechanical performance, durability, and corrosion resistance.

5. A promising direction for future research is the development of multi-component fiber-reinforced concretes with hybrid reinforcement systems incorporating different fiber types.

References

1. Pukharenko, Yu.V. *Scientific and Practical Foundations for the Formation of Structure and Properties of Fiber-Reinforced Concrete*. Extended Abstract of Doctoral Dissertation. Saint Petersburg, 2005. 42 p.

2. Zubova, M.O. *Fine-Grained Concretes Reinforced with Basalt Fibers and Complex Modifying Admixtures*. Extended Abstract of Candidate Dissertation. Volgograd, 2014. 21 p.

3. Buchkin, A.V. *Corrosion-Resistant Fine-Grained Concrete Reinforced with Fine Basalt Fibers*. Extended Abstract of Candidate Dissertation. Moscow, 2011. 21 p.

4. Chhi, Sovann. *Fine-Grained Fiber-Reinforced Concrete Based on Composite Binders for Monolithic Construction under the Conditions of Cambodia*. Extended Abstract of Candidate Dissertation. Ulan-Ude, 2015. 26 p.

5. Naaman, A.E. Fiber Reinforced Concrete: Five Decades of Progress. *Proceedings of the 4th Brazilian Conference on Composite Materials*. Rio de Janeiro, Brazil, 2018, pp. 1–22.

6. Kalugin, I.G. *Foam Concrete Reinforced with Basalt Fibers*. Extended Abstract of Candidate Dissertation. Krasnoyarsk, 2011. 22 p.

7. Kostrikin, M.P. *Dispersed Reinforced Concrete Incorporating Synthetic Macrofibers*. Extended Abstract of Candidate Dissertation. Saint Petersburg, 2022. 24 p.

8. Kazlitin, O.V. *Fiber-Reinforced Concrete for Monolithic Construction*. Extended Abstract of Candidate Dissertation. Belgorod, 2013. 22 p.

9. Kazlitin, S.A. *Fiber-Reinforced Concrete for Heavy-Duty Industrial Floors*. Candidate Dissertation. Belgorod, 2012. 167 p.

Fediuk, R.S. *Cement-Based Composite Materials for Special Structures*. Extended Abstract of Doctoral Dissertation. Belgorod, 2022. 39 p.