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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

INVESTIGATION OF METHODS FOR IMPROVING THE DEFORMATION PROPERTIES OF CONCRETE USED IN THE CONSTRUCTION OF TRANSPORT STRUCTURES

Speciality: 3305.07 – Construction materials and products

Field of science: Technique

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GENERAL CHARACTERISTICS OF THE WORK

Relevance and degree of elaboration of the topic. In recent years, the road network of the Republic of Azerbaijan has been developing rapidly. Improving the quality of road surfaces (increasing their strength and durability), ensuring the safety and comfort of traffic flow, technical and architectural-aesthetic design of road structures and, in general, solving other issues that constitute the components of the complex operation of roads are brought to the fore. At the same time, the construction of new airfields in this economic zone in connection with the liberation of Karabakh from occupation once again emphasizes the need for work in this direction. The use of high-quality construction materials in the construction of road surfaces and international airports is one of the urgent issues in the transformation of the Karabakh Economic Region into a convenient area for international transportation.

To ensure construction efficiency, one of the main issues facing civil engineers is improving the quality of building materials, as well as saving building materials or using more economical building materials. At the same time, the requirements of State Standards for the degree of strength and durability of building, road and bridge structures have significantly increased. This dictates the need to further improve reliable and durable materials and structures that require minimal costs. As in all areas of the construction industry, the requirements for the properties of concrete used in the construction of transport structures have been tightened. This is due, on the one hand, to the low resistance of cement concretes to the impact of loads on transport devices, and on the other hand, to a further increase in the aggressive impact of the environment.

It is known that although cement concrete has relatively high compressive strength, its tensile and bending strengths are low. At the same time, concrete in transport facilities is constantly exposed to dynamic loads, frost in winter, and aggressive water in bridges over rivers. Concrete used in such facilities must have high density, high strength, and high crack resistance. The effectiveness of using high-modulus fibers to increase crack resistance, which is one of the main shortcomings of concrete, has been theoretically substantiated and experimentally proven.

Thus, the importance of increasing the density of concrete arises, one of the most effective ways to solve this problem is to use dispersed fibers in concrete. In this case, there is a significant increase in the mechanical properties of concrete (strength, cracking and impact resistance), as a result of which the durability of the structure increases, resistance to aggressive media increases (an increase in density weakens the interaction of the concrete matrix with aggressive substances) and dispersed reinforcement spreads in the concrete matrix prevent the formation and propagation of cracks.

Recently, the use of fiber concrete in the construction of various types of structures has led to major advances in solving these problems. However, it should be noted that fiber materials increase the properties of concrete, such as strengthening and crack resistance, only at the macro level. There are large voids between the coarse aggregates, fine aggregates, and cement particles. The use of particles smaller than cement particles to fill these voids leads to a more dense structure of cement concrete.

In order to create transport facilities with high operational and technical properties, one of the necessary issues is the modification of fiber concrete mixtures with complex additives - that is, increasing the strength of fiber concrete at the micro level. In other words, it is possible to obtain fiber concrete with high deformation properties by adjusting its microstructure, and improving the quality of hard road surfaces with the use of such concretes, as well as developing a calculation methodology, is one of the urgent issues.

The object and subject of the research. The object of the research work is fiber concrete, and the subject of the research work is the improvement of the properties of fiber concrete for road construction at the microlevel.

The purpose and tasks of the research work. The purpose of the research work is to theoretically, experimentally and computationally substantiate the effectiveness of using fiber concrete to improve the deformation properties of concrete used in transport construction. To achieve this goal, it is important to address the following issues:

- selection of the optimal composition of fiber concrete with high resistance to cracking;
- study of the strength and deformation properties of fiber concrete;
- study of the composition of fiber concrete modified with complex additives through physical and chemical research methods;
- study of the change in strength parameters and economic efficiency of fiber concrete road pavement and tunnel lining construction;
- preparation of a computer model of fiber concrete transport facilities and study of the process of their operation under load;
- development of fiber concrete production technology;
- development of the technology of using fiber concrete in transport facilities.

Research methods. In the implementation of the research work, physical, mechanical and physicochemical analysis methods were used, as well as the SAP 2000V4 program in the report of the fiber concrete road pavement and the tunnel top cover plate. X-ray spectroscopy, radiography, differential thermal analysis, microprobe and electron microscopy analysis methods were used from the physicochemical research methods. Experimental studies were carried out in the “Construction Materials Scientific Research and Testing Laboratory” accredited in the ISO 17025-2020 system under the “Materials Science” department of the Azerbaijan University of Architecture and Construction.

Provisions submitted for protection:

1) the feasibility of using fiber concrete in the composition of hard road wear, resistance to aggressive influences;

2) spent optimal composition of fiber concrete with high operational and technical properties;

3) experimental results of the study of the dependence of the properties of fibrobeton on the amount of fibromaterial;

4) chemical and mineral composition providing high technical properties of fiber concrete;

5) method of accounting for high-quality pavement based on modified fiber concrete with complex additives;

6) the construction of the pavement and the overlap of the tunnel, providing uniform reinforcement throughout the volume of concrete and thereby uniform distribution of the stress falling on the structure.

Scientific novelty of research work. For the first time, the effect of complex additives on improving the properties of fiber-reinforced concrete used in the construction of transport facilities has been studied, and the effectiveness of their application has been proven theoretically and experimentally.

1. The effectiveness of the complex use of high-modulus fibers, chemical modifiers and ultradisperse additives in eliminating the most important drawback of road concrete, crack resistance, has been theoretically substantiated, the reinforcement-matrix interaction has been established, and the effect of the interaction on the mechanical properties of concrete has been evaluated.

2. The optimal composition of fiber concretes with high operational properties has been developed, and the improvement of the deformation properties of fiber concrete by fiber material has been experimentally proven.

3. The regularities of the effect of highly fine mineral additives and chemical additives on the formation of the structure of fiber concrete have been studied and it has been determined that the use of complex additives ensures the production of calcium hydrosilicates, which leads to a more dense, microcrack-free matrix of fiber concrete.

4. For the first time, the possibility of increasing the effectiveness of the application of fiber concretes in road construction has been realized by optimizing its composition at the microlevel, which led to an increase in the strength of the composite material by 30%.

The practical importance of the work. The composition of fiber concrete with high construction and technical properties (compression strength 60 MPa, bending strength 28 MPa) was chosen, the production technology was developed and on its basis its use in the construction of pavement and tunnel facing pan was justified. This allows you to expand the material base for the construction of road surfaces and other transport structures. A technology for the manufacture of solid road surfaces containing fiber concrete has been developed.

Validity of results. The reliability of the results obtained was confirmed by modern analysis methods (the high deformability properties of fiber concrete were confirmed by physical-mechanical and physical-chemical analysis methods) and mathematical modeling methods.

Approval and application of work. The important results of the presented dissertation work were discussed and presented at the following international and national conferences:

International conferences:

- "World Science" Proceeding of the II International Scientific and Practical Conference "Methodology of Modern Research", Dubai, UAE, March 28-29, 2016.
- III International Azerbaijani-Ukrainian Scientific and Practical Conference. Baku - Poltava. 01-02 June 2020.
- STRAHOS 2022, 19th Seminar of Track Management Proceedings –Žilinská univerzita v Žiline. Poprad, Slovakia. Part 1. 2021.
- STRAHOS 2022, 19th Seminar of Track Management Proceedings - Žilinská univerzita v Žiline. Poprad, Slovakia. Part 2. 2022.

Republican conferences:

- International conference on “Development prospects of the construction materials industry in Azerbaijan” dedicated to the 40th anniversary of the Azerbaijan University of Architecture and Construction. Baku, Azerbaijan. December 15, 2015.
- Scientific and practical conference on “Progressive technologies in the field of architecture, construction and transport”. Baku, Azerbaijan. February 02, 2016.
- Republican scientific and practical conference on “Development prospects of the transport and road complex of the Republic of Azerbaijan”. Baku, Azerbaijan. December 14-15, 2017.
- Republican scientific and practical conference on the topic "Modern problems of using technological machines in construction." Baku, Azerbaijan. 2019.

The research work was discussed at the meetings of the "Transport and Logistics" department of the Azerbaijan University of Architecture and Construction (2015, 2016, 2017, 2022).

The main provisions of the dissertation work were published in 14 scientific articles.

Personal participation of the author. In the implementation of the dissertation work, the author plays the leading role in the analysis of literature sources, the formulation of the problem, the formulation of new ideas, the planning and implementation of experimental work, the interpretation of fundamentally sound results obtained through various research methods, and the writing of articles and dissertations.

Dissertation results. In 2015, Sumgait Chemical Industrial Park LLC was used in the design and construction of the proposed rigid road with fiber concrete coating on an area of 94.3 hectares. Also in 2023, a container terminal project was developed using fiber concrete offered on the territory of Poti TransTerminal OJSC in the city of Poti, Republic of Georgia.

The total volume of the dissertation indicating the separate volume of structural sections of the dissertation: The dissertation consists of an introduction, four chapters, a list of 121 literature used. The dissertation is reflected in 146 pages of computer text, contains 34 tables, 16 graphs and 23 images. The main part of the research work consists of 192845 characters, at the entrance 10256 characters, in chapter I 56027 characters, in chapter II 47088 characters, in chapter III 55576 characters, in chapter IV 21010 characters and a total of 2888 characters.

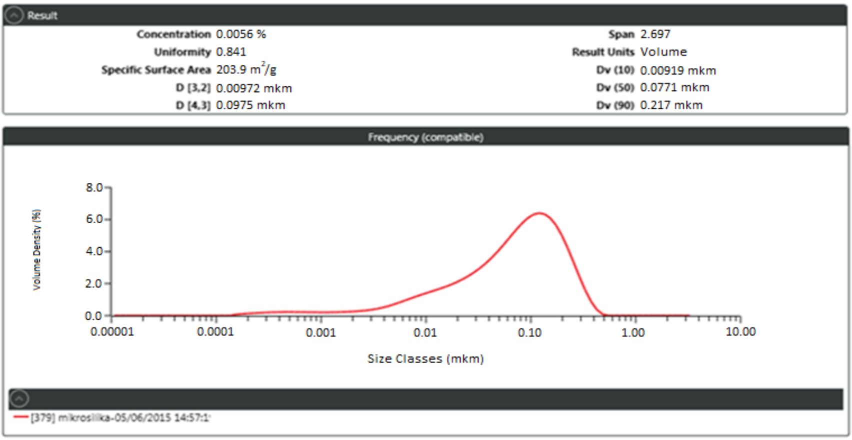
MAIN CONTENTS OF THE WORK

In the introduction, the relevance of the work was substantiated, the goals and objectives of the research work, research methods were presented, provisions for protection were given, the scientific novelty of the work and the practical value of the results obtained were assessed.

The first chapter provides an analytical review of the literature. First, the perspective directions of the application areas of fiber concrete in construction were investigated and extensive information was presented, the characteristics of dispersed reinforcement of cement concretes and the role of the structure of fiber concretes in predicting their properties and the properties of fiber concretes used in the construction of transport facilities were investigated and based on the information obtained, two aspects were identified that formed the basis of the dissertation work: the service life of hard road surfaces with cement concrete coating is longer than the service life of non-hard road surfaces with asphalt concrete coating and the high deformation properties, crack resistance, frost resistance and other construction and technical properties of fiber concretes.

From the analysis of the literature, it can be concluded that the constant exposure of road surfaces to aggressive influences in transport facilities reduces their service life. In order to prevent this, it is of great importance to improve the deformation properties of concrete used in the construction of transport facilities, increase its frost resistance and crack resistance. At the same time, as a result of a large-scale literature analysis, it was concluded that it is necessary to take into account the revolutionary changes in the properties of concrete with the use of various complex additives in the construction of transport facilities. In this case, the calculation of transport facilities will also be different. There is a need to study and calculate the deformation properties of transport facilities based on new generation road surface materials modified with complex additives, which was the main goal of this dissertation work.

The second chapter contains the characteristics of the materials used and the research methods. In the manufacture of fiber concrete, a mixture of fine-grained and heavy concrete was used. In the manufacture of fine-grained concrete from Portland cement of class CEM II/A-P 42,5N, medium-grained sand, crushed stone of 5-15 fractions, MasterAir 125 air receiver (SikaControl-125 AER MA) and microsilica and metal fiber material of type CFV is used. The combined use of chemical additive dispersions reduces the water/cement ratio and makes the structure even denser. Porosity reduction is known to be one of the most effective methods used to prevent corrosion of cement stone and concrete. As a result, the deformation properties of concrete increase significantly[1]. The granular composition and chemical composition of the microsilica additive were determined experimentally (graph 1).



Graph 1. Granular composition of microsilica.

The analysis results show that the particle size of the microsilica is in the range of 0.01-0.1 mkm. These ultrafine particles play an important role in the formation of the concrete microstructure. The chemical composition of the microsilica was also studied, and as a result, it was found that the SiO_2-nin content in the additive was 89%.

This chapter also presents methods for making and characterizing fiber concrete samples. Methods for determining the compression and bending strength of fiber concrete, modulus of elasticity, alkalinity and other deformation properties, methods for

[1]Пути повышения эффективности фибробетона. Ахмедов, Н.М., Ширинзаде, И.Н..

calculating the composition of fiber concrete and calculation of the composition of fiber concrete using selected starting materials are presented here.

Chapter II also provides extensive coverage of the study of the interaction between the concrete matrix and fibrous materials. Both theoretical and experimental methods were used to study this relationship.

The third chapter is devoted to the development of fiber concrete compositions for transport facilities, the study of their properties and the calculation of road surfaces based on modified modern fiber concretes. It was established that the plastic deformation of fiber concrete depends on the nature of the components that make up the concrete composition and the ratio of phases. The effect of the amount of fiber material on the strength of concrete was studied in the research work. As can be seen from Figure 2, the strength of fiber concrete in the AB area of the graph is almost the same as the strength of concrete (matrix). In this zone, the amount of fiber material (per 1 m3) is in the range of 30-40 kg. When using more than 40 kg of metal fibers, part of the excess load is carried by the fiber material and the load-bearing capacity of fiber concrete increases significantly[2]. In the BC area, the impact strength of the fibers is already manifested. In the CD area of the graph, the increase in the strength of the composite material becomes more intense with an increase in the midrar of the fiber material.

Chaotically arranged fibers are connected to each other by a fine-grained concrete matrix. From point D to point E, there is no significant change in the strength of fiber concrete, and at this point the amount of fiber material in the fiber concrete composition is 90-100 kg per 1 m^3. The increase in the amount of fiber material from 100 kg to 110 kg leads to a decrease in the strength of fiber concrete. This is explained by the decrease in the matrix layer filling the gaps between the fibers and, as a result, the stratification of fiber concrete under the influence of loads. For this reason, even with a weak destructive load (5-10 MPa), the material collapses.

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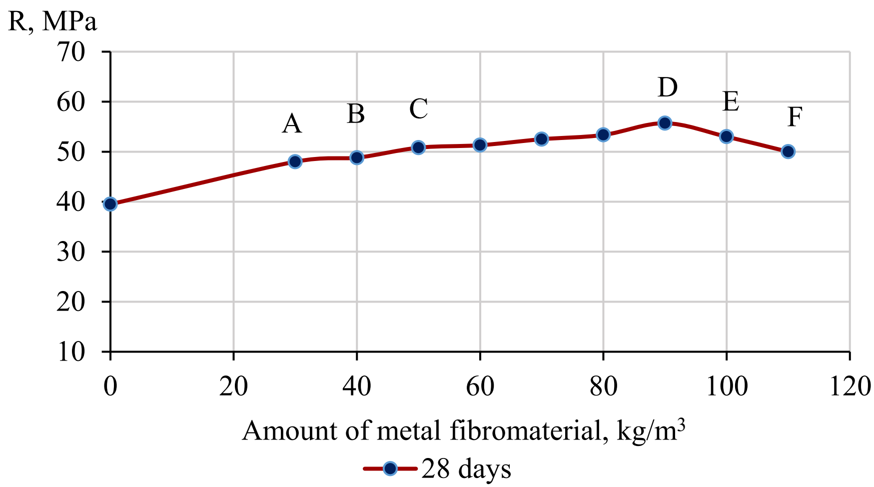
[2]Yol betonlarının dinamiki yüklərin təsirinə dayanıqlığının artırılması üsulları. Əhmədov, N.M., Şirinzadə, İ.N..



Graph 2. Dependence of the strength of fiber concrete on the amount of metal fibers.

Concrete in road pavements is constantly exposed to various loads (during the movement of vehicles) during operation. These stresses deform the structure of the concrete, initially microcracks form, which over time turn into macrocracks and destroy the concrete[3]. The durability of concrete in structures depends on its mechanical properties (tensile strength, compressive strength, and friction, which are the main indicators of its durability), the nature of the bond between cement stone and fillers, the modulus of elasticity, and environmental influences[4].

Taking into account these conditions, complex additives were also used to create a high-strength matrix for fiber concrete. In the preparation of the concrete mixture, a finely dispersed additive (such as microsilica) and an air-entraining additive were used to ensure its density, frost resistance, strength and other construction and technical properties. The properties of fiber concrete are given in table 1.

At the same time, it was studied and found that the use of metal fibro reduced fibrobeton friction by 22%. The use of garnet disperse

[3]Особенности эксплуатации дорог с жесткими покрытиями. Ахмедов, Н.М., Ширинзаде, И.Н..

[4]Применение фибробетона в транспортном строительстве. Ахмедов, Н.М..

additives in the manufacture of fiber concrete reduced its friction by 25% compared to the original concrete mixture[5].

The high deformation properties of concrete used in the construction of road surfaces are of great importance. One of the most important deformation properties of materials is their elasticity. It is known that in the physical sense, concrete is not considered an elastic material, therefore, the use of the term "modulus of elasticity" for concrete is not considered correct. Here, the term "initial modulus of elasticity" can be used, which conditionally characterizes the elastic properties of concrete in areas affected by stress.

Table 1. Properties of concrete

№	Indicators	Test results	
		Plain concrete	Fiber concrete
1	Density, kg/m^3	2200	2700
2	Compressive strength limit, MPa	50	65
3	Bending strength limit, MPa	-	48
4	Drunkenness	W16	W16
5	Frost resistance	F200	F400

To determine the modulus of elasticity of fiber concrete, 8 samples measuring 15x15x60 cm were prepared from the mixture and stored under standard conditions until they reached the brand strength.

The deformation was measured using an indicator attached to the tongues of the samples using a metal frame. The loading of the samples (in a hydraulic press) was carried out in stages. The initial loading was 2% of the expected destructive load.

The deformation was measured at the moment of loading and 5 minutes after the load was applied. The experimental results of the elastic modulus of the samples are given in table 2.

The analysis of the results shows that the compressive strength of fiber concrete is 9.3% higher than that of ordinary concrete samples.

In addition, the modulus of elasticity of fiber concrete is also 2.7% higher than that of concrete samples. The conditional class of

[5] Research of ways increase of constructive durability of concrete in modern transport constructions. Ahmadov, N.M., Shirinzade, İ.N..

concrete is higher than the corresponding concrete class, which indicates that the fibers in the concrete do not have any effect on the strength properties of the samples. It can be assumed that the fibers in the samples do not correspond to the class of concrete, that is, they are small. The fibers in the samples were selected for concrete of class B30, but the addition of fibers was agreed upon for concrete of class B60. The samples had the highest stress values N 4-1 and N 4-2. However, the deformation indicators are approximately the same in all samples. The dispersion of fibers in the samples affects the development of their straightening deformation, the nature of the dispersion, turning brittle dispersion into plastic.

Table 2. Determination of the modulus of elasticity of the samples

Sample name	Amount of fibromaterial, kg/m^3	Destructive load, P_d, kN	Prismatic strength, R_{pr}, MPa	Modulus of elasticity, E_b, MPa	Deformation ε_i
N 1-1	0	1218	54.13	35685	0.0020
N 1-2	0	1220	54.22	36992	0.0021
N 2-1	20	1380	61.33	37474	0.0023
N 2-2	20	1320	58.67	37830	0.0021
N 3-1	50	1380	61.33	37083	0.0022
N 3-2	50	1295	57.56	38237	0.0019
N 4-1	80	1400	62.22	41335	0.0022
N 4-2	80	1430	63.55	39511	0.0023

In addition, the computation parameters of the modulus of elasticity were compared with the parameters obtained from the tests. As a result of this comparison, it was found that the elastic modulus values obtained as a result of tests of class B30 fiber concrete are 2.1% higher than the calculated values.

As noted above, the deformation properties of fiber concrete have been confirmed by experiments conducted depending on the nature of the components that make up its composition. If the modulus of elasticity of fibro-metals is 1.9x10^5 MPa, and the modulus of elasticity of fibrobeton is 39.51x10^3 MPa, then $E_f/E_m>1$, then the tensile strength of fibrobeton will be high, and the breakdown of fibrobeton will occur by plastic deformation.

It is clear that in this case, the collapse of the composite occurs due to the breakdown of the bond between the fiber material and the matrix. That is, the main part of the energy spent on the collapse of fiber concrete is spent on the release of the fiber material from the matrix. Therefore, the load spent on the collapse of fiber concrete depends significantly on the amount of fiber material, the bond between the fiber material and the matrix, and the shape of the fibers.

The goal of this section of the research work is to create a high-strength matrix for fiber concrete. It has been experimentally confirmed that concrete modified with highly dispersed particles and chemical additives can be the strongest matrix for fiber concrete. In order to obtain fiber concrete with high operational and technical properties and long-lasting, it is necessary to achieve technological compatibility of metal fiber and cement matrix and to ensure protection of fiber material from corrosion in this matrix. For this purpose, microsilica, which is used to strengthen the structure of the concrete matrix at the microlevel, is a waste obtained during the production of ferrosilicon, and more than 90% of the composition consists of spherical amorphous SiO_2.

The compaction of the microsilica additive in cement concrete is due to the fact that its particles fill the gaps between the cement and filler grains and can form a new substance. At the same time, as we mentioned above, the air-entraining additive MasterAir 125 (SikaControl-125 AER MA), which is used to form a dense stone, also has a positive effect. The use of such additives further compacts the structure by reducing the water/cement ratio. At the same time, the additive increases the adhesion between the cement and filler particles in the contact zone. It is known that reducing porosity is one of the most effective methods used to prevent corrosion of cement stone and concrete. As a result, the deformation properties of concrete increase significantly[6].

The microstructure of concrete modified with selected additives and also of fiber concrete was studied using a scanning electron microscope FE-CEM QUANTA 400F (Philips, Netherlands) (at the

[6]Development of effective fiber-reinforced concrete compositions used in transportation structures. Ahmadov, N.M., Shirinzade, I.N..

Institute of Geology and Geophysics of the Azerbaijan National Academy of Sciences). The microstructure of the concrete matrix is presented in figure 1.

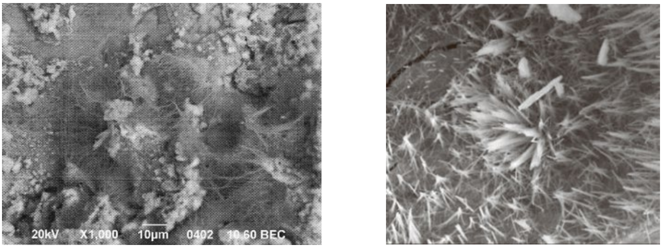


Figure 1. Image of the microstructure of the concrete matrix used for the manufacture of fiber concrete under the FE-CEM QVANTA 400F electron microscope.

As can be seen from the figure, the microstructure of concrete is composed of needle-like, densely packed crystals, which are crystals of low-basic, strong calcium hydrosilicates formed in the system as a result of the reaction of Portland cement with active silica, and it has been scientifically proven that they also give high strength to cement matrices[7].

The third chapter also examined the issue of calculating and studying the process of working hard road pavement with fiber concrete coating. The following layered structure was adopted as the road pavement structure (figure 2).

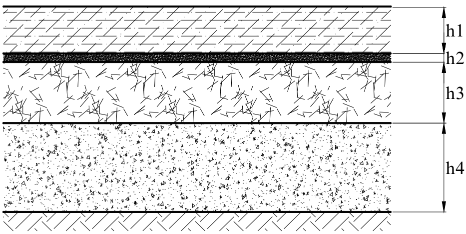


Figure 2. Determination of the materials of the constructive layers and the calculation characteristics of the soil:

1 – Covering – fiber concrete, h_1=22 cm, concrete class B_{btb}=5.97 MPa, E_b=39000MPa;

2 – Leveling layer – sand treated with bitumen, h_2=3 cm;

[7]The modified fiber concrete for railway structures. Ahmadov, N.M., Sadiyev, R.B., Yusifzade, E.N..

3 – Basic – fractional crushed stone – h_3=24 cm, E=350 MPa;

4 – Additional base layer - gravel-sand mixture - h_4=25 cm, E=180 MPa, φ=320, c=0.004 MPa.

Calculated humidity of the ground of the earthen canvas 0.88Wt, modulus of elasticity of the ground E_{qr}=25 MPa, $φ_{qr}$=110, c = 0.008 MPa.

1. Determination of the equivalent thickness of the additional layer of the base and the equivalent modulus of elasticity on the surface of the additional layer of the base.

The calculation of road wear is carried out in the following sequence:

$$E'_e = \frac{E_i}{0.71 \cdot \sqrt{\frac{E_{qr}}{E_3}\operatorname{arctg}\left(\frac{1.35h_e}{D}\right) + \frac{E_3}{E_{qr}} \cdot \frac{2}{\pi}\operatorname{arctg}\frac{D}{h_e}}} =$$

$$= \frac{180}{0.71 \cdot \sqrt{\frac{25}{180}}\operatorname{arctg}\left(\frac{1.35 \cdot 53}{50}\right) + \frac{180}{25} \cdot \frac{2}{3.14}\operatorname{arctg}\frac{50}{53}} = 47.24 \text{ MPa}$$

$$h'_e = 2 \cdot h_4 \sqrt[3]{\frac{E_3}{6E_{qr}}} = 2 \cdot 25 \sqrt[3]{\frac{180}{6 \cdot 25}} = 53 \text{ sm}$$

where, D = 50 cm – the calculated diameter of the wheel track.

2. Modulus of elasticity on a foundation consisting of a fractional crushed stone layer:

$$h''_e = 2 \cdot h_4 \sqrt[3]{\frac{E_3}{6E_{qr}}} = 2 \cdot 24 \sqrt[3]{\frac{350}{6 \cdot 47.24}} = 51.5 \text{ sm}$$

$$E''_e = \frac{E_i}{0.71 \cdot \sqrt{\frac{E''_e}{E_2}}\operatorname{arctg}\left(\frac{1.35h''_e}{D}\right) + \frac{E_2}{E''_e} \cdot \frac{2}{\pi}\operatorname{arctg}\frac{D}{h''_e}} =$$

$$= \frac{350}{0.71 \cdot \sqrt{\frac{47.24}{350}}\operatorname{arctg}\left(\frac{1.35 \cdot 51.5}{50}\right) + \frac{350}{47.24} \cdot \frac{2}{3.14}\operatorname{arctg}\frac{50}{51.5}} = 87.60 \text{ MPa}$$

The calculated tensile strength of fiber concrete in bending is determined.

Fatigue coefficient of reinforced concrete during reloading:

$$K_y = 1.08\left(\sum N_h^{25}\right)^{-0.063}$$

where, N_h^{25}- is the number of design loads on the entire road pavement during 25 years of operation; n_c - number of days with positive temperature during the year;

$$K_y = 1.08(3487153)^{-0.063} = 0.42$$

The tensile stress of the pavement in bending is mainly assigned to the first loading scheme, taking into account the connection of the pavement to the foundation and the loading conditions of the pavement.

3. Calculated flexural strength of fibroconcrete:

$$R_{əd}^{hes} = 5.97 \cdot 1.0 \cdot 0.95 \cdot 0.42 = 2.382$$

4. Determination of calculated load affecting road pavement. Road pavement is calculated according to the first loading scheme.

$$Q = Q_h \cdot m_d = 57.5 \cdot 1.3 = 74.74 \text{ kN}$$

5. Determination of the radius of the wheel track:

$$R = \sqrt{\frac{10 \cdot Q}{\pi \cdot p}} = \sqrt{\frac{10 \cdot 74.75}{3.14 \cdot 0.6}} = 19.92 \text{ kN}$$

6. Determining the thickness of the pavement. Several thicknesses of the cover are determined: h = 16 cm, 18 cm, 20 cm, 22 cm, 24 cm, 26 cm. The elastic parameters of the pavement are determined for all thicknesses:

$$l_y = h \cdot \sqrt[3]{\frac{E_b(1-\mu_0^2)}{6E_e''(1-\mu^2)}} = 16 \cdot \sqrt[3]{\frac{39300(1-0.3^2)}{6 \cdot 87.60(1-0.2^2)}} = 74.52 \text{ sm}$$

$$l_y = 18 \cdot \sqrt[3]{\frac{39000(1-0.3^2)}{6 \cdot 87.60(1-0.2^2)}} = 66.24 \text{ sm}$$

$$l_y = 20 \cdot \sqrt[3]{\frac{39000(1-0.3^2)}{6 \cdot 87.60(1-0.2^2)}} = 82.80 \text{ sm}$$

$$l_y = 22 \cdot \sqrt[3]{\frac{39000(1-0.3^2)}{6 \cdot 87.60(1-0.2^2)}} = 91.08 \text{ sm}$$

$$l_y = 24 \cdot \sqrt[3]{\frac{39000(1-0.3^2)}{6 \cdot 87.60(1-0.2^2)}} = 99.36 \text{ sm}$$

$$l_y = 26 \cdot \sqrt[3]{\frac{39000(1-0.3^2)}{6 \cdot 87.60(1-0.2^2)}} = 107.64 \text{ sm}$$

In the first load scheme, the coating stresses are determined by a relationship reflecting the relationship between the coating and the base, according to the theory of elasticity σ_{pt}, MPa.

For each thickness, density coefficients are determined at known stresses that are on the surface:

$$K_y = \frac{3.150 \cdot 1.0}{5.97 \cdot 1.0 \cdot 0.95} = 0.555$$

$$K_y = \frac{2.797 \cdot 1.0}{5.97 \cdot 1.0 \cdot 0.95} = 0.493$$

$$K_y = \frac{2.529 \cdot 1.0}{5.97 \cdot 1.0 \cdot 0.95} = 0.446$$

$$K_y = \frac{2.356 \cdot 1.0}{5.97 \cdot 1.0 \cdot 0.95} = 0.416$$

$$K_y = \frac{2.261 \cdot 1.0}{5.97 \cdot 1.0 \cdot 0.95} = 0.399$$

$$K_y = \frac{2.181 \cdot 1.0}{5.97 \cdot 1.0 \cdot 0.95} = 0.384$$

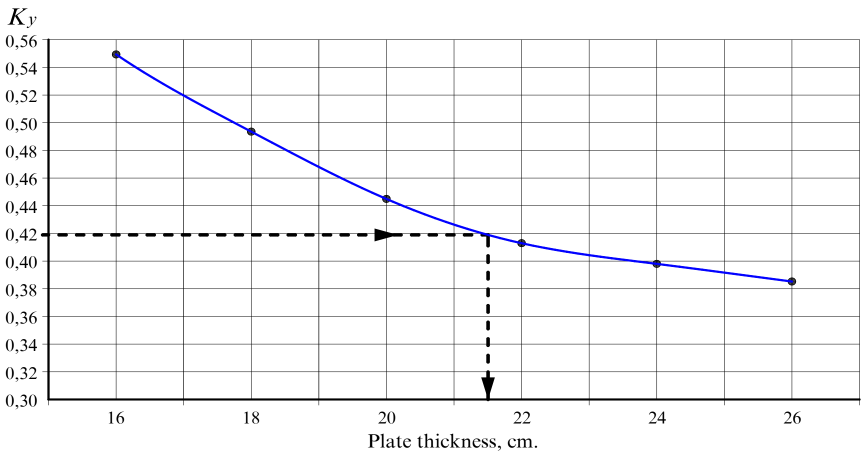
Based on the determined fatigue coefficients of concrete, a dependence graph between the fatigue coefficient and the thickness of the ceiling was constructed (graph 3). Based on the required fatigue coefficient of concrete under repeated loading K_y=0.42, the thickness of the fiber concrete ceiling is determined from the graph and h=22 cm is assumed according to the calculation schemes shown below.

Based on the thickness of the fiber concrete pavement established by the schedule, the strength of the road pavement is checked:

$$K = \frac{R_{əd}^{hes}}{\sigma_{pr}} = \frac{2.382}{2.356} = 1.01 \geq K_m = 1.0$$

The strength condition of the fiber concrete ceiling has been met.

In addition to the rigid pavement structure, a calculation model was developed using SAP2000V14 software and the internal forces and stresses occurring in the cross section of the structure were analyzed. It should be noted that when calculating road structures with a rigid pavement, the influence of the temporary standard load AK-15, used in the calculation of artificial structures, was taken into account. A fiber concrete hard pavement structure with a thickness of 22 cm, a length of 60 m, and a width of 9.0 m was adopted as a model (figure 2).



Graph 3. Graph for determining the thickness of the fiber concrete pavement.

The maximum internal forces in the cross-section of the structure were set: M^1_{max}=23.8 kNm, M^2_{max}=24.5 kNm, Q_{max}=24.9 kN. The obtained results were compared with the relevant construction norms and rules, and the results were analyzed.

$$\sigma = \frac{M}{W} = \frac{24.5}{0.0081} = 3025\frac{kN}{m^2} = 3.02\ MPa$$

$$W = \frac{bh^2}{6} = \frac{1.0 \cdot 0.22^2}{6} = 0.0081\ m$$

$$K_y = \frac{3.02 \cdot 0.94}{5.97 \cdot 1.0 \cdot 0.95} = 0.500$$

The resulting fatigue coefficient of the specified concrete is greater than the calculated coefficient (K_y=0.42), and, according to graph 3, the thickness of the fiber-reinforced concrete corresponding to this fatigue coefficient is h = 22 cm.

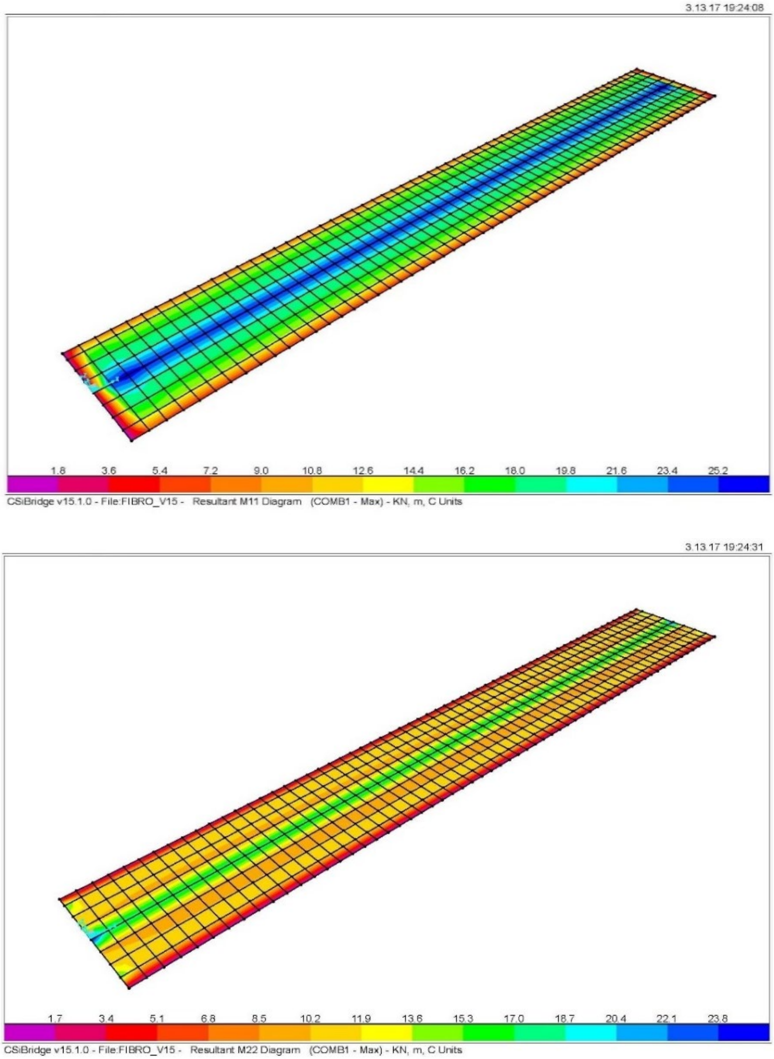


Figure 2. Model of the construction of a rigid road surface.

The fourth chapter is devoted to the proposed technology for the production of modified fiber concrete, the technology for the manufacture of fiber concrete pavements and the calculation of the economic efficiency of fiber concrete pavements.

Although fiber concrete is a new generation of concrete, its manufacturing technology is not very different from that of conventional concrete. As with other concretes, its technology consists of the steps of preparing and mixing materials. However, the manufacture of materials has some distinguishing features from conventional concretes. When preparing fiber concrete, a number of conditions must be observed:

- ensuring uniform distribution of the fiber material in the concrete mixture;
- selecting the optimal combination of the properties of the fiber material with the concrete matrix.

Preparation of the fibre-concrete mixture into a pre-counted amount of sand, crushed stone, cement, metal fibres and microsilics is poured into a mixer, first dry-mixed, then mixed again for 15 minutes with addition of an aerosol additive to water. The flowchart for preparing fiber concrete is shown in figure 3. The dosing error should not exceed 1% ± for glue, water, fibromaterial and additives and 2% ± for fillers[8].

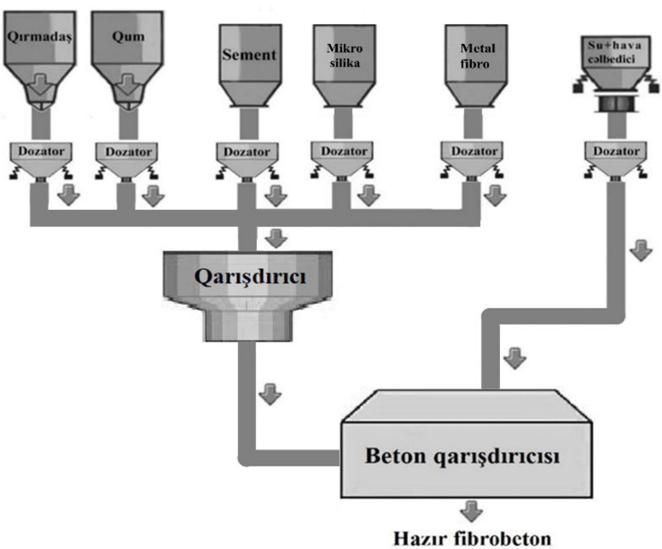


Figure 3. Technological scheme of fiber concrete production.

[8]Modifikasiya olunmuş betonun nəqliyyat qurğularının tikintisində istifadəsi. Əhmədov, N.M., Şirinzadə, İ.N..

The construction of fiber concrete road surfaces should be carried out in dry weather conditions (air temperature should not be lower than 5^0C) and on a dry base.

The construction of fiber concrete road surfaces should be carried out in dry weather conditions (air temperature should not be lower than 50C) and on a dry base.

The construction of fiber concrete road surfaces is carried out in a certain technological sequence. The construction of the road surface is carried out in the VI round. The work and volumes of work performed in each capacity are as follows:

- the main working operations in the first section are: placing the conveyor belt on both sides of the moving part and planning and compacting the separating layer.
- the main working operations in the second section are: transporting the fiber concrete mixture by concrete transport vehicles and uniformly distributing and laying the fiber concrete mixture by a concrete paver.
- the main working operations in the third section are: smoothing the fiber concrete pavement and maintaining the fiber concrete pavement.
- the main working operations in the quadruple section are: opening transverse and longitudinal expansion joints on a hard fiber concrete covering.
- the main working operations in the fifth section are: filling transverse and longitudinal expansion joints with bitumen mastic.
- the main working operations in the sixth section are: removing the imitation wire placed on both sides of the chassis.

Despite the high cost of fiber concrete compared to ordinary concrete, the economic efficiency achieved during its use is significantly higher. This economic efficiency is achieved due to the absence of reinforcement in structures. However, the main reason for the high economic efficiency is that the use of fiber concrete increases the durability of the structure.

The economic efficiency of using fiber concrete in 2 different transport facilities was considered:

1) in the upper cover plate of a tunnel with fiber concrete material;

2) in the construction of a hard road surface with fiber concrete coating.

In the first variant, a 60 cm thick upper cover plate was designed. In order to conduct a feasibility study of the road surface of a highway tunnel, B40 brand ordinary concrete and fiber concrete cover plates with a thickness of 60 cm were calculated and compared with each other.

In the second variant, a fiber concrete road surface is designed, and according to the calculation, the thickness of such a road surface is 22 cm. The amount of materials used for the cover plate of 1 m^2 of the tunnel and for the coating of the road surface with fiber concrete material was calculated. With the use of fiber concrete, 1825 kg of reinforcement was saved for every 10 m of the tunnel with a width of 12.5 m. So, 14.4 kg of fittings were saved per 1 m^2, which means a saving of 2368.85 AZN per 125 m^2.

Although the economic benefit from the use of fiber concrete is mainly due to the reinforcement in reinforced concrete construction, the reduction in the thickness of the road surface when using fiber concrete also increases economic efficiency. When using reinforcement, the cost of materials used for the lining of a 100 m^2 tunnel is 22298.378 AZN, and the cost of materials used in the lining of a fiber concrete tunnel is 24555.378 AZN. This means an additional cost of 2257.0 AZN (10.1%) per 100 m^2. However, the costs incurred for reinforcement work also constitute ~15% of the total cost of work, which ensures the economic efficiency of the use of fiber concrete.

When using cement concrete pavement, due to the reduction in the thickness of the pavement (from 24 cm to 22 cm), it can be said that the price of the materials used changes little. The price of materials used for 100 m^2 of a 24 cm thick cement concrete pavement is 2206.315 AZN, and the price of materials for a 22 cm thick pavement using fiber concrete is 2737.246 AZN. This means an additional cost of 530.93 AZN (24.0%) per 100 m^2. It is clear that although economic efficiency is expressed in terms of the cost per unit of product, the use of high-quality materials plays a more important role in increasing the efficiency of structures and facilities.

The economic efficiency achieved in this case is achieved by extending the service life of concrete due to the increase in its technical indicators, which, if we convert this into numbers, will result in even higher economic efficiency.

Therefore, the expected annual economic benefit from the use of fiber concrete in the construction of road pavements and other transportation facilities is achieved not only by reducing the cost of road pavements, but also by improving the quality of the construction, which is of great importance in an economic environment where competition is strong.

The result

The use of fiber concrete to improve the deformation properties of concrete used in the construction of transport facilities and the studies conducted in this regard have led to the following general conclusions:

1. The deformation properties of concrete used in the construction of transport facilities have been studied and it has been determined that the properties of fiber concrete depend significantly on the nature and ratio of the phases that make up it. When selecting the composition of fiber concrete, the amount of fiber material should be in such an interval that brittle deformation of the product does not occur in this interval.

2. It was determined that the technological compatibility of the concrete matrix and the fiber material can be ensured by the even distribution of the fiber material in the concrete matrix, the sufficient amount of concrete mixture forming the matrix, and at the same time, the convenient placement of the fiber concrete mixture in the mold.

3. It was experimentally determined that the creation of a high-strength matrix for fiber concrete can be achieved by using complex additives (chemical and dispersed additives).

4. It has been determined through physical-chemical research methods that the use of complex additives leads to the formation of a

more dense concrete matrix. The microsilica additive fills the voids, causing the structure of the transition zone to become denser and its strength to increase. At the same time, the formation of calcium hydrosilicates as a result of the reaction of microsilica with the hydration products of cement also densifies the structure. In addition, the air-entraining additive further strengthens the structure by reducing the water/cement ratio.

5. The even distribution of metal fibers throughout the entire volume of concrete ensures the even distribution of the stress on the structure, which creates the basis for ensuring the longevity of transport facilities.

6. It has been established that the use of fibrous materials in concrete increases its plastic deformation during collapse, which leads to an increase in crack resistance and, as a result, the period between repairs increases by 1.8-2 times. At the same time, the use of fiber concrete significantly increases the bending and tensile strength of structures (by 30%) and abrasion resistance. This also increases the reliability of structures and structures exposed to high dynamic and impact loads.

7. The use of fiber concrete in road construction leads to an increase in the service life of road pavement and pavement, and thereby a decrease in operating costs. By using fiber concrete in artificial structures, up to 30% of capital investment can be saved due to a complete or partial reduction in reinforcement work.

8. Fiber concrete was used in the construction of the road surface and a reduction in the thickness of the coating (2 cm) was achieved. When using a cement concrete road surface, the price of the materials used changes little due to the reduction in the thickness of the coating (from 24 cm to 22 cm). However, despite its economic disadvantage, the use of high-quality materials leads to a decrease in operating costs and an increase in the period between repairs.

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Claimant's personal contribution in printed works:

Scientific papers [3, 4, 8, 9, 11] are works prepared independently by the author.

In scientific papers [1, 2, 5, 6, 7, 10, 12, 13, 14] the formulation of the problems, the conduct of experiments, the integration of the obtained results, and the writing of the article belong to the author.

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