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INCREASING THE STRENGTH OF TEXTILE-REINFORCED CONCRETE WITH DURABILITY

ПІДВИЩЕННЯ МІЦНОСТІ ТЕКСТИЛЬНО-АРМОВАНИХ БЕТОНІВ ІЗ ЗАБЕЗПЕЧЕННЯМ ДОВГОВІЧНОСТІ

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Abstract. *High-strength and high-modulus fibers and threads, such as glass, basalt, carbon and others, in combination with a cement matrix form a new class of structural building materials, the so-called textile-reinforced concrete. Currently, concrete reinforced with textile reinforcement is most often used to strengthen existing building structures such as stone panels, roofs, and reinforced concrete beams. Over the past two decades, a significant number of works have been devoted to the development of this direction. The disadvantage of textile-reinforced concrete is the low strength of its matrix during bending and stretching.*

The purpose of the work was to determine a way to increase the strength of the textile-reinforced concrete matrix without losing its durability.

It was found that there is a relationship between the composition of the mixed matrix aggregate and its strength. The dependence of matrix strength on the content of fine aggregate, which includes iron ions, was determined. In the course of the study, it was established that the simultaneous introduction of an aggregate containing iron and a mixture of surface-active substances into the composition of the matrix leads to an increase in its bending strength from 50% to 90%. Thus, the tensile and bending strength of textile-reinforced concrete increases.

It has been proven that the content of surface-active substances in the amount of 0.0004% of the mass of cement in the matrix provides the greatest increase in its strength. This phenomenon occurs without a decrease in the water-cement ratio, which is assumed to be larger than the minimum acceptable for durability. Thus, it has been proven that the flexural strength of textile-reinforced concrete depends mainly on the tensile strength of its concrete matrix, and the strength of textile reinforcement practically does not affect the strength.

To increase the strength of textile-reinforced concrete and ensure its durability, it is advisable to use a mixed aggregate, which is a mixture of river sand and iron ore beneficiation waste, simultaneously with the modification of the water structure using micellar catalysis

Key words*: concrete, textile reinforcement, strength, surfactants, river sand, iron*

Introduction

Steel reinforcement has traditionally been widely used as reinforcement in building structures for more than a hundred years. However, traditional reinforced concrete structures have significant disadvantages. The main one is the irrational use of concrete in the stretched zone, which significantly increases the weight of the structure. The use of prestressed structures only partially solves this problem. The high cost and irrational use of formwork in the manufacture of both prefabricated and monolithic reinforced concrete structures is also a disadvantage of reinforced concrete structures [1].

To date, the proposed steel-reinforced concrete structures are such structures in which reinforced concrete and steel work together. in such elements, reinforced concrete is used to absorb compressive forces, and steel is used to absorb tensile forces [2].

The disadvantages of reinforced concrete include the significant own weight of the structure, which is a consequence of the irrational use of concrete in the stretched area of the structure.

The first attempts to use non-metallic materials as reinforcement, highlighted in work [3], gave an impetus to the development of composite materials of a new type. Currently, high-strength textile materials are finding new applications for reinforcing structural elements in the construction industry [4]. High-strength and high-modulus fibers and threads, such as glass, basalt, carbon and others, are mainly used for their manufacture. In combination with the cement matrix, they form a new class of structural building materials - textile-reinforced concrete, which today is considered one of the most promising materials used in construction. Compared to traditional building materials, textile-reinforced concrete has a number of undeniable advantages, such as high corrosion resistance, less weight of structures, etc.

Survey of external environment

Currently, concretes reinforced with textile reinforcement are mostly used to strengthen existing building structures such as stone panels [5], roofs [6], and reinforced concrete beams [7]. Over the past two decades, a significant number of works have been devoted to the development of this direction. The work [8] describes a systematic approach to the study of concrete reinforced with fibrous composites. The works [8,9] describe methods of measurement and application of structures made of concrete reinforced with composites, as well as methods of production of reinforcing threads and fabrics. In [10], the dependence of the strength characteristics of the composite on the structural parameters of reinforcing rovings and fabrics is considered. Studies [11] describe the use of polymers in composite concrete. Various models are studied in studies [12], such as a computer model of a composite structure made of concrete, models describing the behavior of the structure under the influence of long-term loads and corrosion. In works [13] it is determined that the strength of concrete structures can be increased with the use of prestressed textile fabrics. In general, the technology of using a reinforcing mesh made of high-strength rovings has a number of advantages compared to reinforced concrete.

The mechanism of operation of the reinforcing fiber in the cement matrix is very different from that in the polymer matrix due to the lower limit of the elongation of the former, which is significantly less than the elongation of the fibers. Therefore, in cement composites, the matrix is destroyed before the strength properties of fiber reinforcement are fully realized.

Destructive processes in concrete, such as the occurrence of internal stress, the formation of structural microcracks, changes in geometric dimensions, etc., are mainly caused by shrinkage phenomena of cement stone, which in most cases leads to cracking of concrete. This is especially important for thin-walled textile concrete.

Designated textile-reinforced concrete (TAB), regardless of the field of application, must have certain general properties. Namely, sufficient strength and high speed of its formation, which will ensure a reduction in the manufacturing time of such concrete products and structures or a reduction in the construction time.

One of the disadvantages of many "cement-water" systems is their sufficiently low speed of structure formation, and therefore the main properties of building structures made on their basis. Thus, for the hydration reaction of cement minerals, the usual transformation time is several weeks or even months, therefore, the search for effective methods of accelerating these reactions is an urgent task.

To accelerate the hardening of textile-reinforced concrete in the production of structures, various methods are used: increasing the specific surface of cement; the effect of elevated concrete hardening temperature, both at normal atmospheric pressure and at elevated pressure; introduction of additives that accelerate hardening. However, each of these methods has its own drawbacks. An increase in the specific surface of cement has its limitations both in terms of the value, the excess of which leads to the reverse aggregation of cement particles, and in terms of increasing the costs of concrete production. Heat treatment of concrete also has its limitations. Even according to regulatory documents, in order to obtain high-quality (including frost-resistant) concrete, it is necessary to reduce the isothermal heating temperature to 333K. Traditionally, hardening accelerator additives are used to solve the problem of accelerating the formation of concrete strength. However, their drawback is interference in the chemical processes of hardening of binders, in particular, changes in their orientation and the formation of new "non-standard" minerals. That is, traditional methods of accelerating chemical processes (use of high temperatures, chemicals) most often do not give the desired result. In addition, they act indiscriminately, accelerating side reactions, leading to the appearance of unwanted products in the system.

At this time, the application of various types of catalysis to accelerate almost all reactions used in organic chemistry became a stable trend. Even those transformations that were previously carried out without the use of any catalysts are now involved in the circle of catalytic processes, which reflects the general general direction. To regulate the properties of textile-reinforced fine-grained concrete, the most promising methods are the methods of liquid phase activation, which represent various types of processing of liquid components of the concrete mixture, which, in comparison with solid-phase mechanical activation of the binder and aggregate or the introduction of chemical additives into the concrete mixture, can provide an increase strength of concrete with a significant reduction in the costs of additives and binder [14]. However, at the same time, the theory of activation of liquid components of the concrete mixture [15] is not sufficiently developed to date, the mechanism of its influence on the structure and properties of cement composites has not been identified, rational compositions, methods of preparation and production of fine-grained concrete have not been determined.

Interest in solutions of organic substances arises due to their general ability to structure water molecules and promote peptization of binder particles, i.e., play the role of a catalyst in chemical reactions [16] and a regulator of the structure of textile-reinforced concrete. This indicates the relevance of research into the possibility of obtaining high-performance textile-reinforced fine-grained concrete based on activated water systems. There are well-known studies [17], which show the influence of complex binders, as well as work [18], which shows the influence of iron-containing components, and work [19] shows the influence of the amount of iron-containing filler on the properties of fine-grained concrete. But only in the paper [20] was studied the deformability of fine-grained modified concrete.

The purpose of this work is to study the influence of mixed aggregate [18-20] and water activated by the use of micellar catalysis [21] on the strength of TAB with its rational location in the structure.

Inputs data and methods

In the research, Portland cement SEM 42.5 (PJSC "Heidelberg Cement Kryvyi Rih"), fine aggregate - iron ore beneficiation waste (VZZR) of the Novokrivorizka mining and beneficiation complex of JSC "Arcelor Mittal Kryvyi Rih" (Ukraine) were used for the production of concrete, which have a maximum particle size 0.63 mm. and Dnieper river sand.

A polyethylene mesh with a hole size of 0.8 mm was used as a fabric.

The components of the concrete mixture were dosed in the necessary quantities, according to the experiment plan, and mixed with a laboratory mixer for 3 minutes. The resulting mixture was placed in a metal mold. The form containing the concrete mixture was rigidly fixed on the laboratory vibration platform and compacted by vibration until complete compaction, which was characterized by the cessation of settling of the concrete mixture and the cessation of the release of air bubbles. After the completion of laying and compaction of the concrete mixture in the form, the open surface of the sample was smoothed with a trowel. For the first 24 hours, the concrete samples were hardened under normal conditions, while they were stored in forms covered with a damp cloth until formwork. This excluded the possibility of moisture evaporating from them in a room with an air temperature of (293 ± 5) K. 24 hours after production, the concrete samples were removed from the forms and placed in a chamber that provided their surfaces with normal conditions, that is, a temperature of (293 ± 3) K and relative air humidity (95 ± 5)%. In the chamber, the samples were placed on the substrates so that the distance between them, as well as between the samples and the walls of the chamber, was at least 5 mm. The main indicator of the quality of the studied concrete was its compressive strength limit. Determination of the strength of the samples was carried out using the universal testing machine UMM-100.

Research results, discussion and analysis of results

Based on the results of the analysis of studies given in [13], the authors stated that the behavior of TAB during stretching is similar to the behavior of ordinary reinforced concrete. Three stages are observed in the tensile diagram, as shown in Figure 1. Stage I corresponds to concrete stretching without cracking and continues until its tensile strength properties are realized. Stage II is accompanied by the formation of cracks in concrete with an almost flat slope of the curve. Also at this stage, tensile deformation is accompanied by partial peeling of the reinforcing roving threads from the matrix. Then the process moves to stage III, which is the final state. External loads are taken by fabric reinforcement, i.e. TAB loses its integrity and can be further used with the formation of cracks and with a greatly reduced stiffness compared to section I. The main difference of this tensile diagram compared to steel reinforcement is the lack of a yield section. Thus, the destruction of the TAB occurs after the completion of the loading stage I, the limit of which corresponds to the tensile strength of the TAB - f_{tab} and the value of the strength of the fabric - f_t, which acts as a reinforcement, is practically leveled off and has no particular significance when exceeding f_{tab}.

This analysis shows that the increase in tensile strength of TAB is provided primarily by the tensile strength of the concrete matrix.

To increase the bearing capacity of the TAB, it is necessary to increase the limit of the first stage of loading. For this, various researchers suggest increasing the strength of the cement matrix by reducing the water-cement ratio.

However, this decision cannot be accepted, since it is known that a decrease in the water-cement ratio below a certain value leads to a decrease in the durability of concrete and, therefore, TAB.

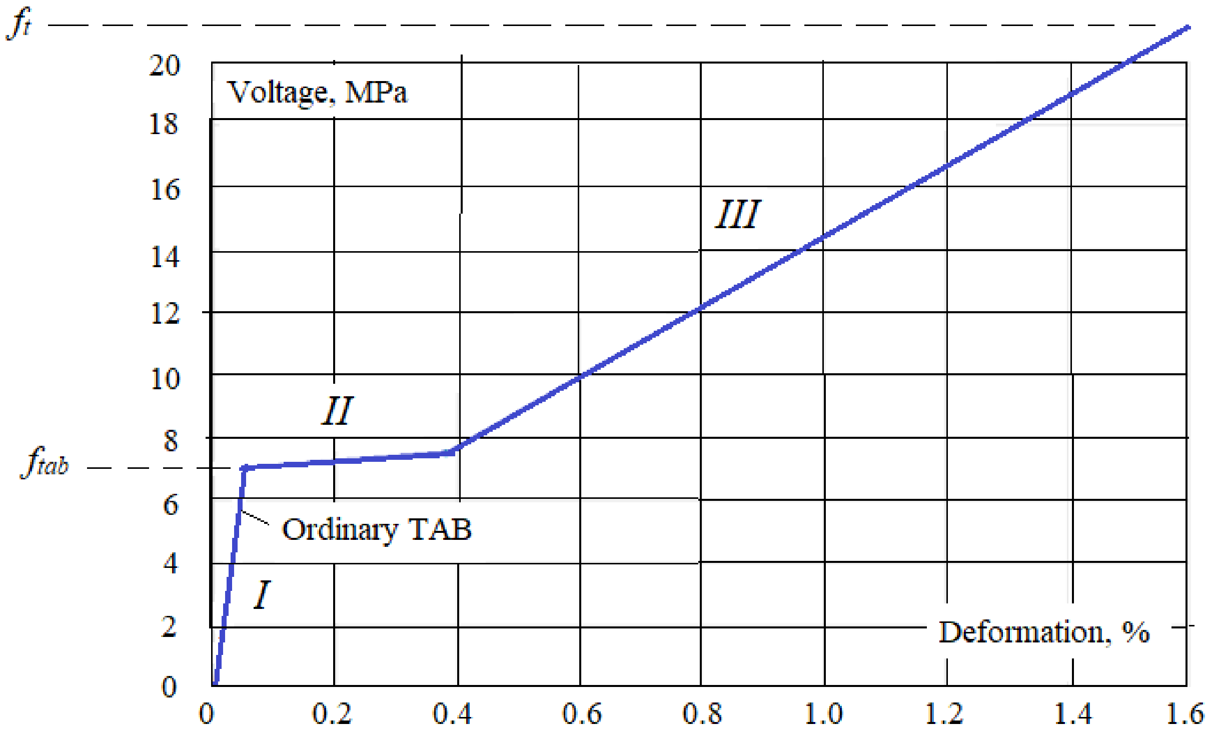

Figure 1 – Dependence between stresses and strains in TAB

This is based on the following results of research and calculations.

The processes of hydration of cement, although sluggish, continue (of course, in the presence of moisture) for decades. A natural question arises from this - if the structure of the cement stone has already developed, "ossified", then what can happen to the material during further hydration of the cement? Where do neoplasms come from? And will something similar to sulfate corrosion of concrete happen, when the formation of a "cement bacillus" leads to the destruction of the material due to the manifestation of wedging deformations, with a parallel increase in the volume of the material and a decrease in its strength and other related characteristics?

I. N. Akhverdov indicated the possibility of the occurrence of the named phenomenon when the relative water content of the cement dough is less than 0.63. Based on similar theoretical premises, some authors [22-23] experimentally confirmed the fact of self-destruction of cement stone made with a water-cement ratio below a certain critical value (different for each researcher) during long periods of operation. Thus, to increase the tensile strength of TAB, it is necessary apply such methods that provide a solution to the specified problem without reducing the water-cement ratio.

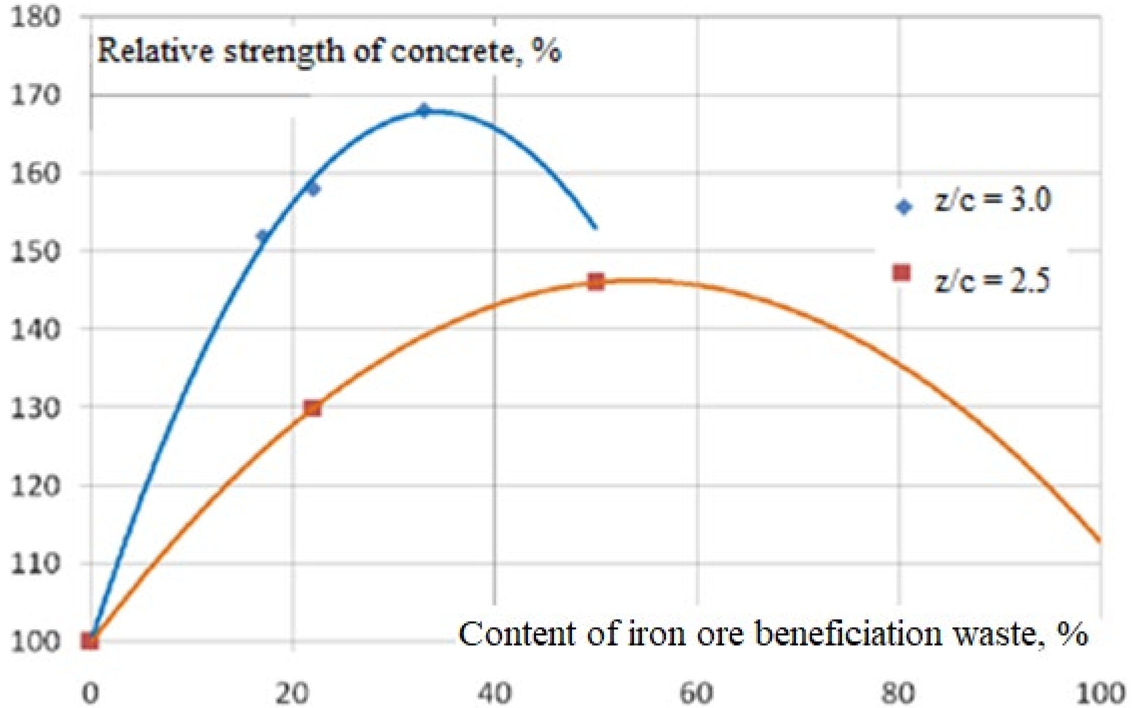

Figure 2 – The influence of the content of iron ore beneficiation waste (WZZR) in the aggregate on the strength of concrete (W/C = 0.5; Z/C is the ratio of the mass of fine aggregate to the mass of cement)

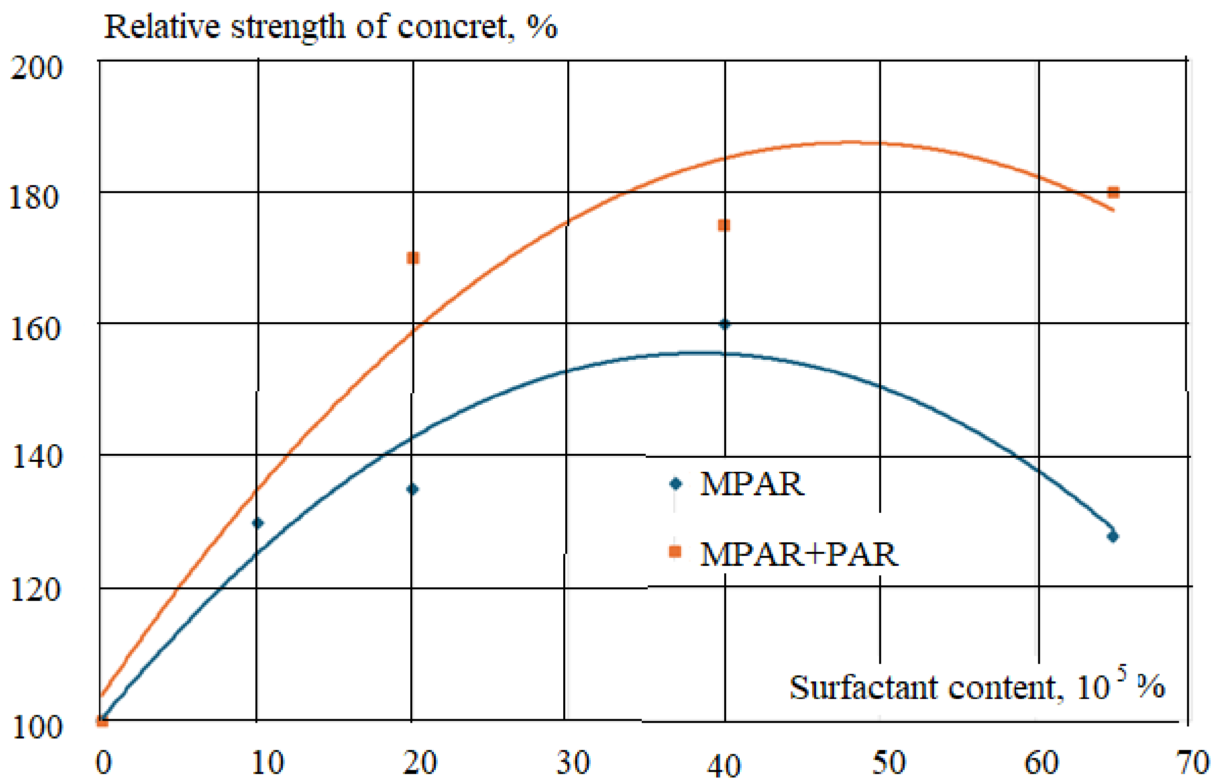

Figure 3 – The influence of surface-active substances on the strength of TAB (MPAR - surfactant that forms micelles, PAR - molecular surfactant)

Such methods, obviously, include the methods proposed in works [18-20], which consist in using as a fine aggregate a mixture of river sand and VZZR, as well as micellar catalysis to modify the structure of water [21].

The results of determining the effect of a mixture of river sand and VZZR (Fig. 2) and a mixture of surface-active substances on the strength of concrete (Fig. 3) show the possibility of significantly increasing the strength of fine-grained concrete without reducing the water-cement ratio.

Based on the knowledge about the nature of the origin of the used components of the cement matrix of the resulting composition, the further increase in the structural strength of the composite binders probably occurs due to the growth of neoplasms during the hardening of the "cement - VZZR - water - surfactant mixture" system. The sequence of hardening is determined by the different intensity and time of interaction of the mineral component of polygenetic quartz, magnetite and hematite with the hydration products of clinker minerals. Regionally metamorphosed (chalcedony-like) generation of quartz from VZZR wastes - ferruginous quartzites, intensively binds calcium hydroxide, and dynamo-metamorphic and contact-metamorphic varieties act as substrates and centers of crystallization.

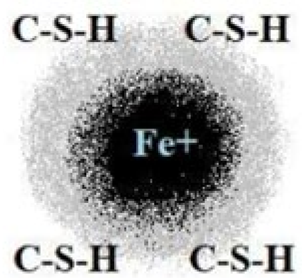

Figure 4 – Scheme of interaction of iron ions with calcium silicates

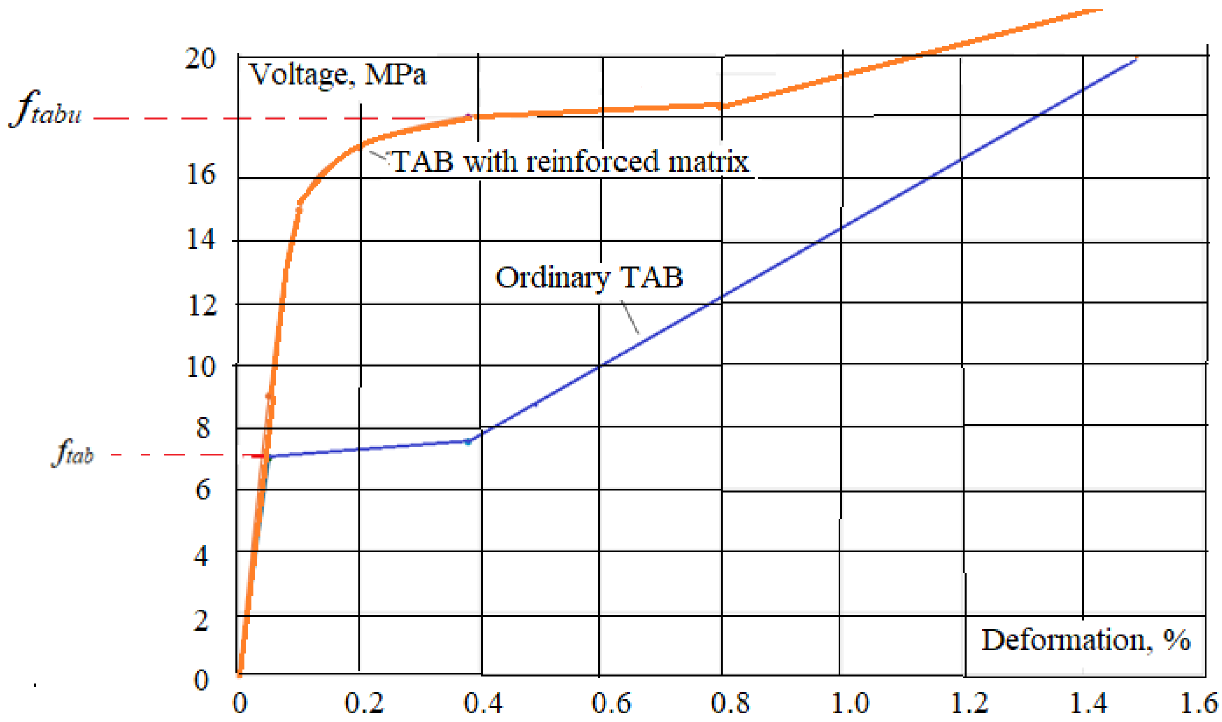

Figure 5 – Dependence between stresses and deformations in TAB

Due to the high electrostatic potential, iron-containing (up to 17% of the weight of iron oxide) magnetite and hematite attract calcium hydrosilicates, providing an adsorbing effect and serving as substrates for neoplasms (Fig. 4).

The use of such concrete as a TAB matrix makes it possible to significantly increase its bending strength from f_{tab} to f_{tabu} (Fig. 5). However, the strength of the fabric used as reinforcement remains unattainable, that is, it is not used to its full extent.

Conclusions

The results of the conducted research allow us to draw the following conclusions:

1. The bending strength of textile-reinforced concrete depends mainly on the tensile strength of its concrete matrix. The strength of textile reinforcement practically does not affect the bending strength of this concrete.

2. An increase in the tensile strength of the concrete matrix must occur without reducing the water-cement ratio below a critical value that ensures the durability of concrete. In this case, it is advisable to use a mixed aggregate, which is a mixture of river sand and iron ore beneficiation waste, simultaneously with the modification of the water structure using micellar catalysis.

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Анотація. *Високоміцні та високомодульні волокна та нитки, такі як скляні, базальтові, вуглецеві та інші у поєднанні з цементною матрицею утворюють новий клас конструкційних будівельних матеріалів, так званий текстильно-армований бетон. На цей час бетони, армовані текстильною арматурою, найбільше використовують для підсилення існуючих будівельних конструкцій типу кам'яних панелей, покрівель, залізобетонних балок. За останні два десятиліття розвитку цього напряму було присвячено значну кількість робіт. Недоліком текстильно-армованого бетону є мала міцність його матриці при згині та розтягу.*

Метою роботи було визначення способу підвищення міцності матриці текстильно-армованого бетону без втрати нею довговічності.

Виявлено, що наявність зв'язку між складом змішаного заповнювача матриці та її міцністю. Визначено залежності міцності матриці від вмісту дрібного заповнювача, до складу якого входять іони заліза. У ході дослідження встановлено, що одночасне введення до складу матриці заповнювача, який містить залізо, та суміші поверхнево-активних речовин призводить до підвищення її міцності при згині від 50% до 90%. Тим самим збільшується міцність текстильно-армованого бетону при розтягу та згині.

Доведено, що вміст поверхнево-активних речовин в кількості 0,0004% від маси цементу в матриці, забезпечує найбільший приріст її міцності. Це явище відбувається без зменшення водоцементного відношення, яке прийнято більшим за величиною ніж мінімально припустиме за довговічністю. Таким чином доведено, що міцність на вигин армованого текстилем бетону залежить головним чином від міцності на розтяг його бетонної матриці, а міцність текстильної арматури практично не впливає на міцність.

Для підвищення міцності текстильно-армованого бетону із забезпеченням його довговічності доцільно використовувати змішаний заповнювач, який являє собою суміш річкового піску та відходів збагачення залізної руди, одночасно з модифікацією структури води за допомогою міцелярного каталізу

Ключові слова: *бетон, текстильна арматура, міцність, поверхнево-активні речовини, річковий пісок, залізо*

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