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INFLUENCE ASSESSMENT OF MICRO SILICA ADDITIVE WITH PLASTICIZER ON PROPERTIES OR FINE-GRAINED FIBER CONCRETE

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ABSTRACT: The paper presents the results of the study of the effect of micro silica on the strength of fine-grained fiber concrete. The possibility of using micro silica as a partial replacement for Portland cement in the composition of fiber concrete has been studied. The cement replacement ratio was 5%, 10%, 20%, and 30% of the binder weight. A reference concrete mixture was also prepared. The authors performed tests to determine the setting time of cement dough with different percentages of micro silica. In the presented work micro silica, a complex additive based on polycarboxylate (MasterGlenium 27) and polypropylene fiber was used. Analysis of the results shows that such additives increase the compressive strength and flexural tensile strength depending on the dosage and change in the time of setting. The optimal composition of fiber concrete using micro silica and plasticizer based on polycarboxylate has been selected, which makes it possible to reduce cement consumption while improving the physical and mechanical characteristics of fiber concrete. It was shown that fiber concrete with the addition of micro silica together with plasticizer MasterGlenium 27 has high physical and mechanical properties.

Keywords: Fiber concrete, Polypropylene fiber, Setting time, Micro silica.

1. INTRODUCTION

The development of construction imposes several new requirements for construction materials, in which the leading role is played by concrete. The main task of the implementation of environmental policy is to create a resource-efficient system of disposal and recycling of industrial waste and secondary raw materials, in particular in the production of building materials and products of given properties. The use of fine-grained concrete is because they do not contain coarse aggregate. In the production of fine-grained concrete, unresolved problems are not enough high flexural strength, and high cement consumption. Many researchers propose to solve these problems using fibers of different compositions and structures [1-8]. In modern construction the most promising are fibrous concretes made with the use of cement fillers and hyper plasticizer.

Fibers are distributed in the concrete mixture during mixing, binding the internal structure of the cement stone, as a result of which the concrete becomes stronger, and more durable, with high-performance properties. Dispersed reinforcement will reduce the concentration of stresses, prevent the development of micro- and macro-cracks and increase the crack resistance of fiber concrete [9-10].

The most important and promising direction of utilization of industrial by-products is their introduction into the construction and production of building materials. Numerous studies show that fly ash, micro silica and metakaolin have been used to obtain high-quality modified concretes [11-12]. The development of technology for obtaining a new generation of concretes consists of the proper selection of compositions and application of complex modifying additives.

The most expedient, according to many scientists, is the use of triple systems "Superplasticizer - micro silica - mineral filler". The interaction of calcium hydroxide in cement with active mineral additives in the presence of water and plasticizer at normal temperatures leads to the formation of compounds with binding properties. The type and amount of additives in the mixture are determined by the requirement for concrete and concrete mixture [13].

Kazakhstan has accumulated a huge amount of various man-made wastes. One of the ways of their utilization is their use as the main component in the production of fine-grained fiber concrete.

More promising in terms of resource efficiency is the use of modifiers containing amorphous micro silica, which is a more accessible and environmentally safe waste of ferroalloy production. The use of micro silica in the composition of the binder can reduce cement consumption in fine-grained concrete. The results of many studies on the impact of micro silica on the properties of cement dough, concrete mixture, and concrete, given the experience of its industrial use, have shown a real possibility of saving cement up to 40% [14].

In the Karaganda region - a region with an unfavorable environmental situation, the main sources of waste products are enterprises of coal mining, metallurgical industry, as well as thermal energy, which generate and dispose of a large amount of waste in the form of fly ash, blast furnace slag, micro silica, etc., in the dump [15].

Microsilica has an ambiguous effect on the cement hydration rate, formation, and precipitation of crystalline hydrates and acts as an additive - gas pedal of cement hydration [16-19].

The main disadvantage of fine-grained concrete based on a multicomponent binder is its high specific surface area, which causes increased consumption of cement and mixing water at the stage of preparation of the mixture and shrinkage of the cement stone during hardening. It is the increased consumption of cement and water that worsens the rheological properties and quality of the hardened concrete. These factors, along with the properties of the materials used and the hardening regime parameters have a huge impact on moisture, carbonation, and contractural shrinkage of fine-grained concrete, which ultimately affects the strength and performance indicators of the quality of concrete and fiber concrete.

Fine-grained concretes have a high homogeneity, polyfunctionality, and the possibility of directional regulation of their construction and technical properties by using local materials, man-made products, and various technological methods.

When using micro silica in the concrete mixture, it is necessary to take into account that due to the high dispersion and amorphous structure, the presence of micro silica causes an increase in water consumption, so it should be combined with a superplasticizer or as part of a complex additive [20-22].

2. RESEARCH SIGNIFICANCE

This paper deals with the application of micro silica and methods of its activation to modify the structure of cement stone and concrete based on it. Concerning any type of filler, in particular, micro silica are relevant questions: how and how much to introduce, and what mechanisms are included in the process of structure formation? Modern technologies and researches in the field of reactive components of natural and man-made origin allow taking a new look at the problems connected with the improvement of the technology of obtaining high-quality concrete.

3. MATERIALS AND METHODS

The methodological sequence of laboratory tests consists of:

1. Determining the timing of the setting (start and end of setting). Figure 1.

Fig. 1 Determination of the setting time

2. Evaluation of the compressive strength of fiber concrete samples. Figure 2.

Fig. 2 Determination of compressive strength

3. Assessment of bending strength of fiber concrete samples. Figure 3.

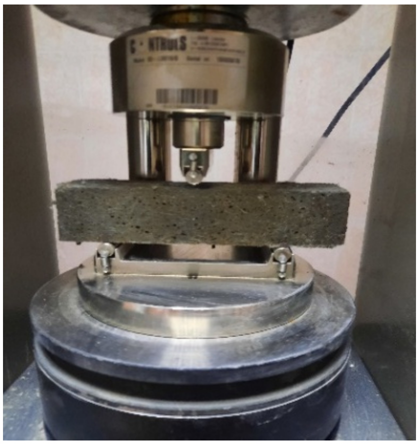

Fig. 3 Determination of bending tensile strength

To investigate the effectiveness of the combined effect of the complex additive (micro silica +

MasterGlenium 27), samples were prepared from normal-thickness cement dough reinforced with polypropylene fiber. Polypropylene fiber was used as a fiber filler. According to earlier studies, the optimum content of polypropylene fiber was 0.5% of the weight of the cement. The main physical and mechanical characteristics of the used fiber are given in Table 1.

Table 1 Main characteristics of reinforcing fibers

Characteristics	Values
Density, kg/m^3	910
Length, mm	3 – 12
Diameter, µm	22
Tensile strength, MPa	170 – 260
Elongation to break, %	150 – 250

The effect of additives on the setting time of the cement system was determined by the requirements of ASTM C403/C403M-08 «Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance».

Determination of the compressive strength of control and modified cement-sand mortars was carried out on samples-cubes measuring 100×100×100 mm, and at bending on beam samples with dimensions 40×40×160mm. To study the properties of fine-grained fiber concrete, samples were prepared from concrete mixtures with different ratios of micro silica with an additive and polypropylene fiber according to BS EN 12390 Testing hardened concrete – Part 3: Compressive strength of test specimens.

The strength value was determined as the arithmetic average of 5 samples for each curing period (3, 14, 28 days). The content of MasterGlenium 27 was 0.8% of the cement weight, micro silica 5%, 10%, 20%, and 30% of the cement weight.

For the experimental work as a binder used Portland cement PC400D0 without addition, the true density was 3100 kg/m^3, bulk density was 1100-1600 kg/m^3. As a fine fraction of the aggregate used natural quartz sand with particle size modulus 2.23. As a plasticizer additive used plasticizer MasterGlenium 27 (BASF Central Asia), density at 20 ° C was 1.05 g / cm^3. The optimum dosage of superplasticizer according to the manufacturer's recommendations is 0.8% of the weight of Portland cement.

Microsilica is represented by tiny spherical particles of amorphous silica, producer LLP «Tau-Ken Temir», Karaganda region. The average specific surface area of micro silica is 20m^2/g, and the granulometric composition is 0.1 microns, which is 100 times smaller than the average grain size of cement. Microsilica was introduced into concrete mixtures at the stage of mixing fine aggregate with cement. The chemical composition of micro silica is shown in Table 2.

Table 2 Chemical composition of microsilica

Oxides content	%
SiO_2	85,500
$Al_2 O_3$	1,210
SO_2	0,717
$Na_2 O$	1,470
$K_2 O$	2,060
CaO	0,466
Cl	0,270

Consumption of raw materials of cement mortar samples (required for measuring the setting time) is presented in Table 3.

Table 3 Composition of cement mortar

Type of concrete mixes	Cement, g	Micro silica, %	MasterGlenium 27, %	Water, g
Type 1	400	-	-	120
Type 2	380	5 %	-	120
Type 3	380	5 %	0.8 %	116,8
Type 4	360	10 %	-	120
Type 5	360	10 %	0.8 %	116,8
Type 6	320	20 %	-	120
Type 7	320	20 %	0.8 %	116,8
Type 8	280	30 %	-	120
Type 9	280	30 %	0.8 %	116,8

The consumption of raw materials of cement mortar samples required for the determination of strength is presented in Table 4.

Table 4 Composition of fiber concrete mixtures

Type of concrete mixtures	Type 1	Type 2	Type 3	Type 4	Type 5
Cement, g	460	455	450	440	430
Sand,g	1450	1450	1450	1450	1450
Micro silica, % of cement weight	-	5	10	20	30
The polypropylene fiber, % of cement weight	-	0,5	0,5	0,5	0,5
MasterGlenium 27, % of cement weight	-	0,8	0,8	0,8	0,8
Water, g	190	186,8	186,8	186,8	186,8

4. RESULTS

Figure 4 shows the results on the setting time of cement dough with micro silica together with the additive.

The addition of micro silica in optimal quantities leads to a change in the setting time compared to the control. The addition of micro silica together with MasterGlenium 27 accelerates the setting time of the cement dough, both in the beginning and in the end. This may be due to the acceleration of the hydration processes of cement dough in the early terms in the presence of active SiO_2.

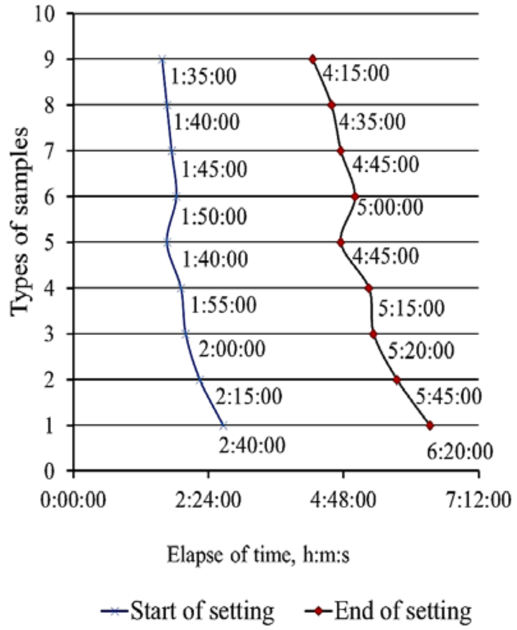

Fig. 4 Timing of setting of the cement mixture

The analysis of the results shows that the addition of MasterGlenium 27 with micro silica (30%) changes the setting time from 2:40:00 to 1:35:00, and the end of 6:20:00 to 4:15:00. Reducing the time of setting can be explained by reducing the amount of water which is achieved plasticizing effect MasterGlenium 27. It can be assumed that the combination of plasticizer MasterGlenium 27 and micro silica was selected in optimal proportions. Individual application of the individual components of the complex additive multifunctional action does not allow for a complex effect at the same time setting time.

Figure 5 shows two curves, the dependence of changes in the total setting time depending on the percentage of micro silica, one curve with no plasticizer, the second with a plasticizer. In both cases, there is a clear pattern of decreasing setting time with increasing micro silica content.

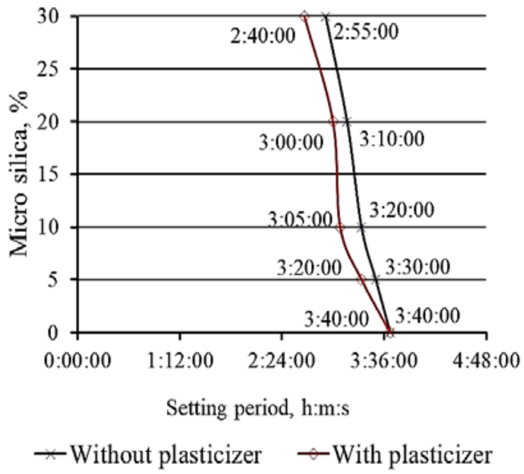

Fig. 5 Dependencies of changes in the total setting time depending on the percentage of micro silica content

The difference in the individual values of the two curves with the same percentage of micro silica indicates the effect of the plasticizer on the reduction of the setting time. According to the results, the best performance in terms of reducing the time of setting is observed for samples of type 8 and 9, which corresponds to the maximum content of micro silica, equal to 30%. However, the main factor for selecting the optimal composition remains the evaluation of the strength characteristics of the samples.

The results of determining the compressive strength of fiber concrete specimens are shown in Figures 6-10.

The reference samples of type 1 (without the use of micro silica) showed the lowest strength compared to the other types. The individual strength values range from 10.55 to 44.91 MPa (Fig. 6).

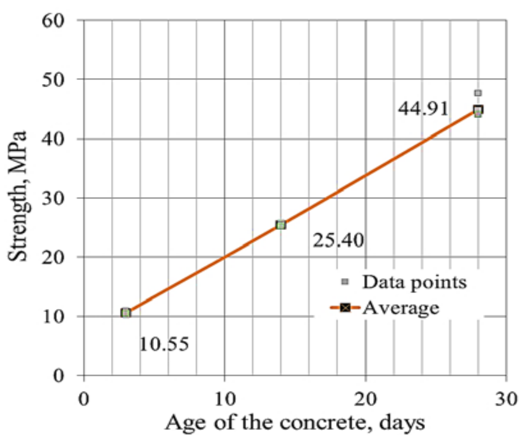

Fig. 6 Results of determining the compressive strength without adding micro silica (Type 1)

Type 2 samples showed a strength exceeding that of Type 1 (Fig.6) by approximately 26.13%. Partial strength values range from 15.50 to 45.42 MPa (Fig. 7).

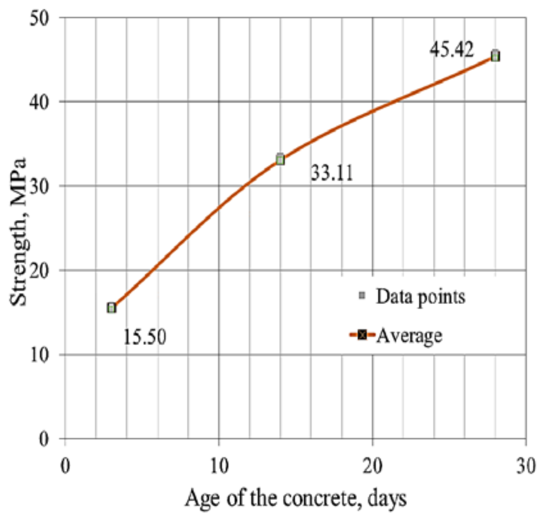

Fig. 7 Results of determining the compressive strength with the addition of micro silica 5 % (Type 2)

Type 3 samples (Fig. 8) showed higher strength than type 1 samples, by 45.86%, and type 2 by 15.02%. Particular strength values range from 19.44 to 48.80 MPa.

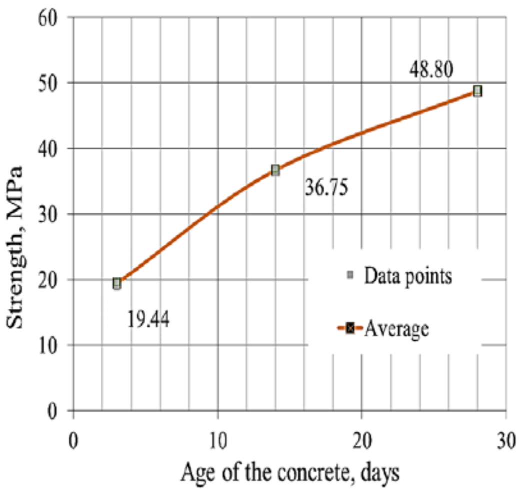

Fig. 8 Results of the determination of the compressive strength with the addition of 10 % micro silica (Type 3)

Type 4 samples (Fig. 9) showed the highest strength, exceeding the strength of type 1 by 58.92 %, type 2 by 24.07 %, and type 3 by 7.92 %. Particular strength values range from 22.25 to 50.10 MPa.

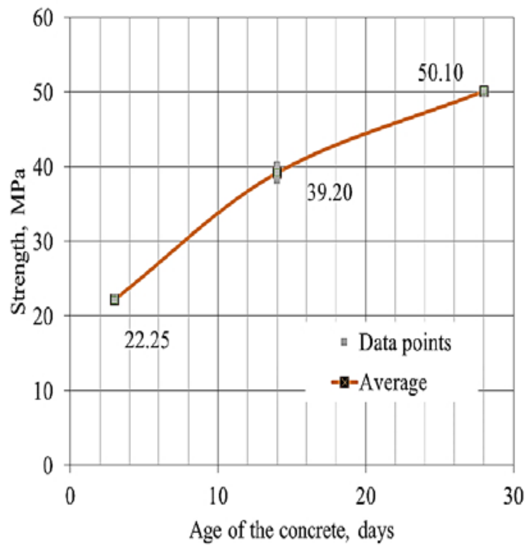

Fig. 9 Results of determining the compressive strength with the addition of 20 % micro silica (Type 4)

Samples of type 5 (Fig. 10) have a strength value ranging from 13.32 to 45.20 MPa.

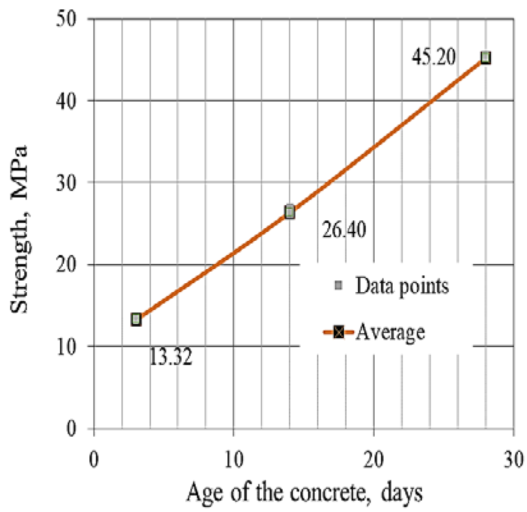

Fig. 10 Results of determining the compressive strength with the addition of 30 % micro silica (Type 5)

The analysis of the data presented in Figures 6-10 shows that a greater value of the strength of fiber concrete at 28 days (50.10 MPa) is achieved with the introduction of micro silica 20% of the weight of cement compared to the control samples without additives (44.91 MPa).

The test results showed that when replacing the cement with micro silica in the amount of 20% (type 4), the compressive strength increased by an average of 58.92%. Increasing the amount of micro silica up to 30% (type 5) leads to a decrease in strength. This is a consequence of the fact that with a small volume of micro silica in the cement the limitation of the volume of free water in the system and the increase in the content of coagulation contacts is compensated by the weakness of these contacts due to the shell of adsorption-bound water around the particles. In addition, it is possible, for the reason that the volume of micro silica is still imperfect to obtain a continuous medium with a special complex.

Figures 11-15 show the changes in the bending strength of the samples as a function of curing time.

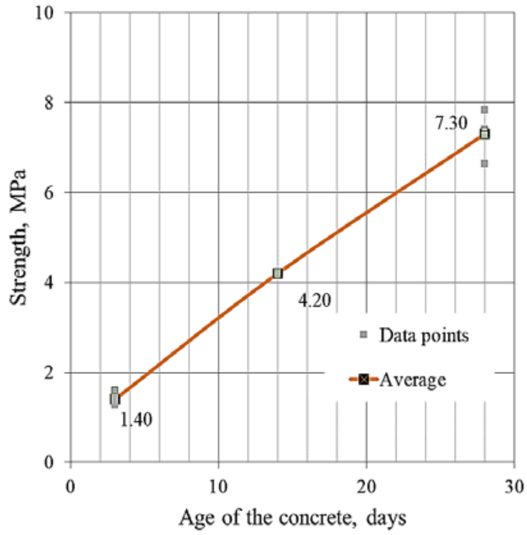

Fig. 11 Results of determining the bending tensile strength without adding micro silica (Type 1)

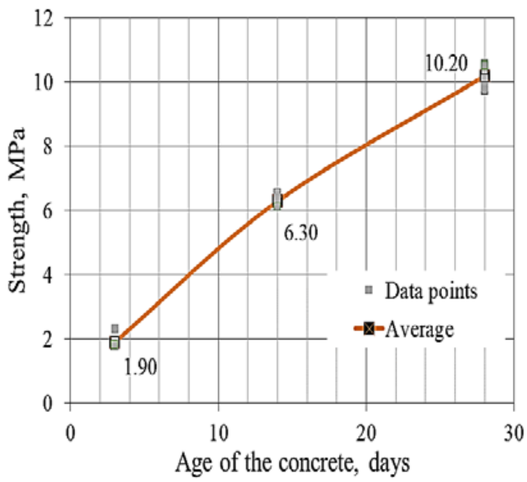

Fig. 12 Results of determining the bending tensile strength with the addition of micro silica 5% (Type 2)

According to the strength comparisons shown in Figures 11-12, specimens using micro silica 5% of cement weight (Type 2), on the 3rd and 14th day showed an increase in strength to an average of 42.5% compared to type 1. On the 28th day, the tendency of strength increase is preserved.

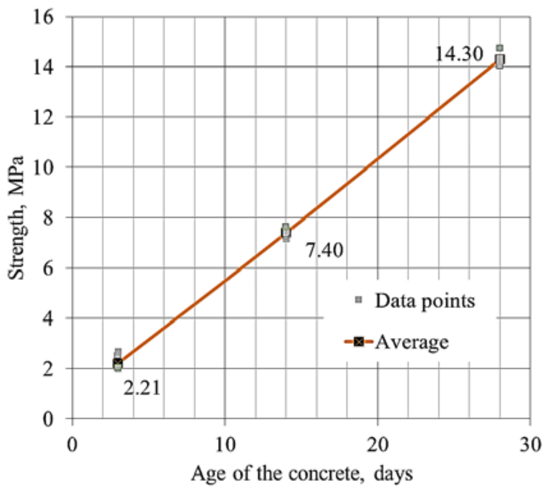

Fig. 13 Results of determining the bending tensile strength with the addition of micro silica 10% (Type 3)

Type 3 specimens (Fig. 13) showed higher strength than type 1 specimens, by 76.5 %, and type 2 by 24.73 %. Particular strength values range from 2.21 to 14.30 MPa.

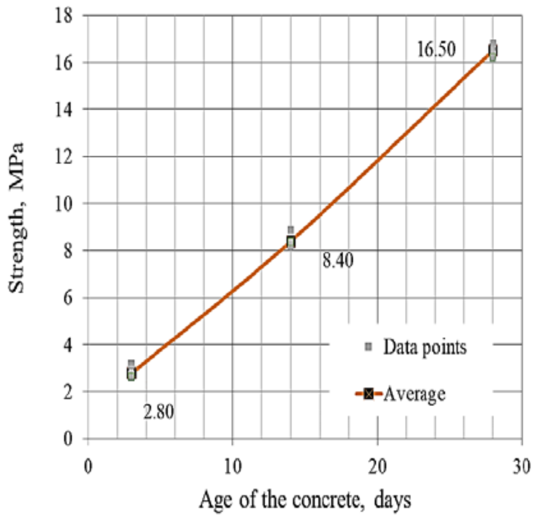

Fig. 14 Results of determining the bending tensile strength with the addition of micro silica 20% (Type 4)

The higher value (Fig. 14) of the flexural strength (Fig. 14) of fiber concrete at 28 days (16.50 MPa) is achieved with the introduction of micro silica 20% of the weight of the cement compared to the control samples without additives (7.30 MPa).

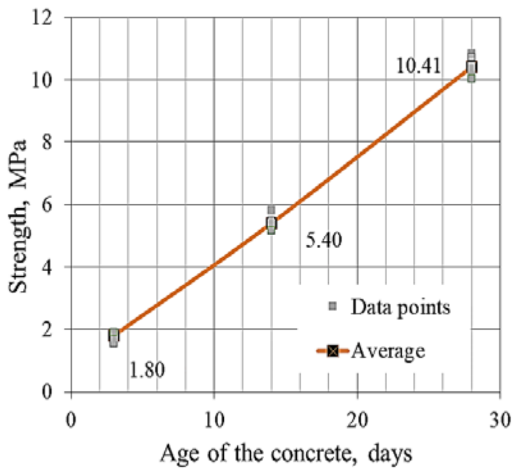

Fig. 15 Results of determining the bending tensile strength with the addition of 30 % micro silica (Type 5)

According to the test results shown in Figures 11-15, the maximum average flexural strength of the control samples is 7.3 MPa (28 days), while the maximum average strength of specimens using micro silica (20% of the weight of the cement) is 16.5 MPa.

Analyzing the obtained data, it should be noted that the maximum effect was achieved with the introduction of micro silica in an amount of 20%, the strength of which was 16.5 MPa.

5. CONCLUSIONS

The following conclusions can be made based on the experimental studies:

1. It was discovered that the introduction of micro silica with the additive MasterGlenium 27 changed the time of setting the start from 2:40:00 to 1:35:00, and the end of 6:20:00 to 4:15:00.

2. The addition of 20% micro silica to the weight of cement in fiber concrete increases the compressive strength under natural curing under normal conditions by an average of 58.92%.

3. The addition of 20% micro silica from the weight of cement in fiber concrete increases the bending tensile strength at 28 days of hardening by 16.5 MPa.

4. Reducing the consumption of cement, by replacing it with micro silica, has a positive effect on the physical and mechanical characteristics of fiber concrete.

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