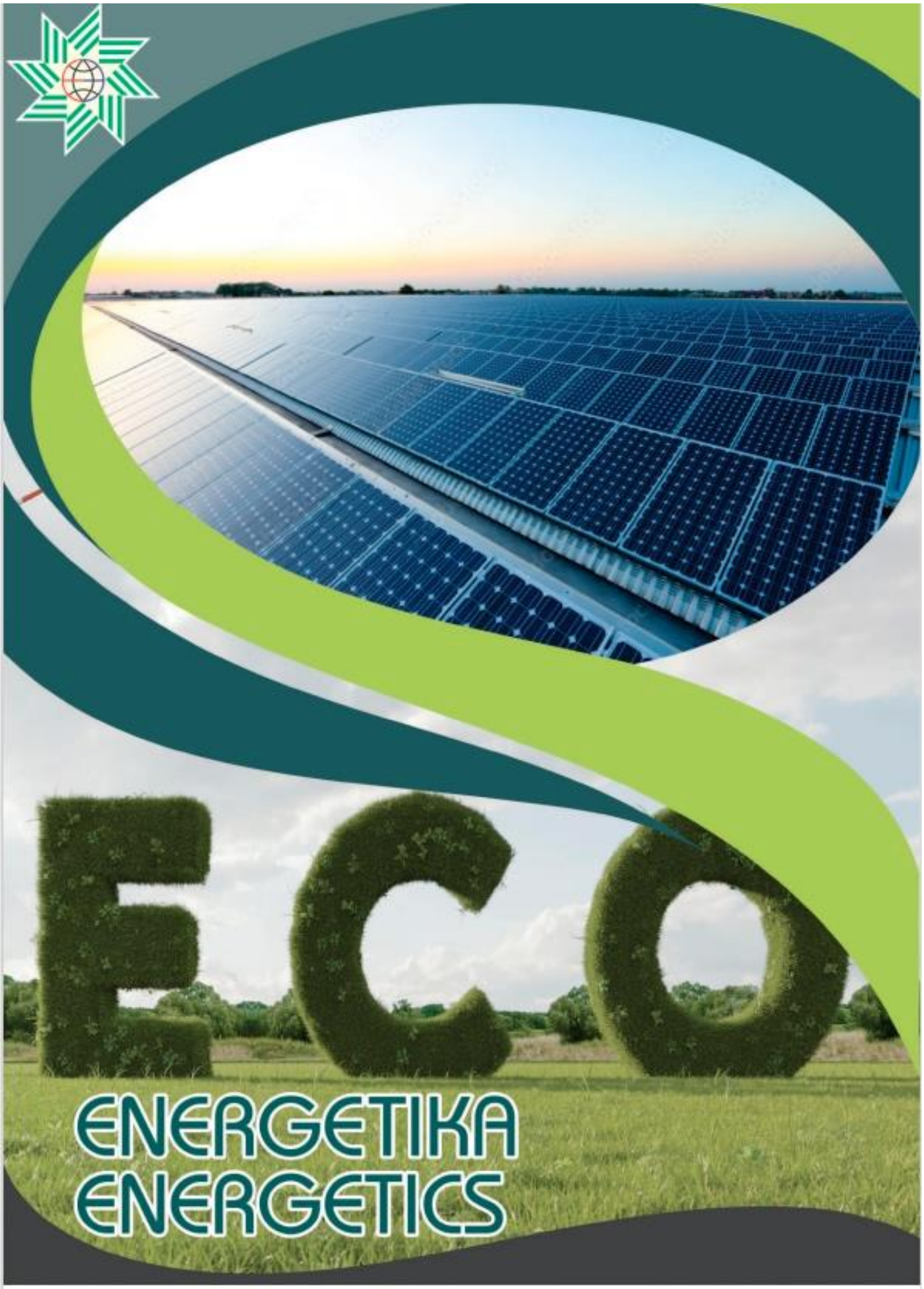
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5, M.Rahim, AZ-1073, Baku Azerbaijan
Tel.: 99412 538-23-70, 99412 538-40-25
Fax: 99412 538-51-22

E-mail: info@ieeacademy.org
ekoenergetics@gmail.com
Internet: http://ieeacademy.org
www.innovationresearch.az

CONTENTS

Development of self-leveling concrete mix composition based on composition adhesive

A.A. Guvalov, Z.R. Alekperov

Azerbaijan Architecture and Construction University, Baku, Azerbaijan

abbas-guvalov@mail.ru

Abstract. The effect of the composition of the adhesive composition on the physical and mechanical properties of self-compacting concrete has been determined. It has been established that even when a third mineral additive is added to the ready-made adhesive composition, the compressive strength of concrete decreases by 10-15%. Such an additive is inert in the composition of self-compacting concrete and does not participate in the hydration process of cement and does not react with portlandite. Therefore, the optimal content of mineral additives in the composition of the composite adhesive is 12-20% by mass of cement. Since the pulverized limestone and limestone added to the cement have a higher specific surface area than Portland cement, when interacting with water, the pulverized limestone reacts with the portlandite formed as a result of hydrolysis. Then, individual particles of pulverized limestone and limestone increase in volume (swell) and thereby fill the voids in the self-compacting concrete, which leads to the compaction of its structure. When increasing the amount of superplasticizers to increase the fluidity of the mixture and make it self-compacting, the process of separation of components occurs in the system. Therefore, finely dispersed additives are added as a mandatory component to self-compacting concrete. These additives interact with the portlandite formed during the hydration of cement and create additional cementitious compounds, as well as remove segregation of the mixture from the black.

Keywords: Composite adhesive, Self-leveling concrete, Compressive strength Limit, pulverizing superplasticizer, Finely dispersed additive.

1. INTRODUCTION

Recently, more and more attention is paid to energy- and resource-efficient materials in the construction industry every year. In this regard, in modern construction, high-tech concrete mixtures are increasingly used, which are capable of independently filling molds, including densely reinforced or complex geometric shapes, without using any external mechanical influences, while maintaining consistency.

Due to their properties and structure, self-compacting concrete solves two problems in construction at once: they have higher strength characteristics compared to conventional concrete, and also reduce the duration and labor costs of construction. In addition to the above, such concretes have high formability and the ability to quickly gain strength, which allows them to be classified as "highly functional concretes".

This is possible through the use of complex modifiers consisting of effective thickeners, viscosity modifiers, active mineral additives and components that accelerate hardening [1,2]. The form-filling capacity of concrete is ensured by the high deformability of the cement paste, which is achieved through the use of effective superplasticizers, an optimal water-cement ratio and the use of mineral additives (fillers) with a constant granularit [3,4]. At the same time, dispersed particles smaller than 90 microns in a volume of 500-600 kg/m3 ensure the resistance of the concrete mixture to stratification [4,5]. To increase the ability of the concrete mixture to overcome obstacles, it is necessary, first of all, to optimize the granular composition of the fillers, reduce the consumption of large fillers and, accordingly, increase the amount of fine filler, limit the size of large particles and increase the amount of cement paste to reduce the friction of the fillers [7,8].

For self-compacting high-performance concrete, Okamura gives the following values: while the yield strength of heavy concrete is 100-1000 Pa, the SCC is less than 60 Pa, while the viscosity of the mixture is close to that of heavy concrete and is 20-200 Pa.s [9].

The current lack of application of self-compacting concrete in Azerbaijan is due to the complexity of their production, as well as the lack of a fully developed regulatory documentation base. Summarizing the above, it can be concluded that the problem of widespread use of self-compacting concrete in our Republic is very relevant today.

The purpose of the current research work is to optimize the composition and study the properties of self-compacting concrete based on a composition adhesive.

2. EXPERIMENTAL DETAIL

The following materials were used when preparing self-compacting concrete samples:

- cement: Portland cement with limestone and pulverizing additives CEM II/A-(P+L)-42.5, AZS EN 197-1-2021 “Composition, technical requirements and conformity criteria for general-purpose cements";
- two types of fine aggregates: Bahramtepe river sand (Mir=1.6), Guba sand (Mir)=3.2;
- Guba crushed stone with a fraction of 5-10 mm, M1000;
- microsilica and metakaolin were used as fine dispersed aggregates;
- hyperplasticizing additives: Betonmix HP 1212, Betonmix HP 1211A.
- Quality and properties of fine aggregates QOST 8735-88 “Sand for construction works. Testing methods” and QOST 8736-2014 “Sand for construction works. Technical conditions”.

Before preparing a sample for testing, the flowability of the concrete mixture is found in accordance with the requirements of QOST 10181-2014. The diameter of the spread of the self-compacting concrete mixture is taken as an indicator of flowability.

The ready-made concrete mixture is poured into a standard cone installed on a metal base. Before the experiment, the cone and all devices are cleaned and wiped with a damp cloth. Filling with concrete mixture is carried out three times, each time the concrete mixture is rammed 25 times. During filling, the cone must be tightly pressed against the container. After compaction of the concrete mixture, its excess is cut off in the same way as the upper edge of the cone [10].

Then, the cone is smoothly removed from the concrete mixture and the diameter of the mixture is determined by the following formula (D).

$$D = \frac{(D_1 - D_2)}{2}$$

Where, D_1-maximum diameter of the spread, mm;

D_2-diameter of the spread in the perpendicular direction, mm.

After determining the flowability, the prepared mixture is placed in cube molds with a size of 150 mm and covered with a damp cloth to prevent moisture evaporation. The temperature of the room where the samples are stored should be within t=20±5°C. After 24 hours, the samples are removed from the molds, after which they are kept in a hardening chamber for 28 days under normal conditions (t = 20±5°C, relative humidity of the air 95 ± 5%).

One of the main testing methods is the determination of the compressive strength of self-compacting concrete. The compressive strength is determined in accordance with the requirements of QOST 10180-2012 "Concrete. Methods for determining the strength of control samples".

By selecting the basic composition of the components of the self-compacting mixture, we studied the following:

1 – the effect of the composition of fine aggregate on the strength limit of the self-compacting mixture,

2 – the effect of the composition of the composite adhesive on the strength limit of the self-compacting mixture,

3 - the operational properties of concrete samples.

The result of the study is the selection of the optimal composition of the concrete mixture for obtaining high-strength self-compacting concrete samples.

To achieve the goals, self-compacting concrete mixtures were prepared using composite adhesives of different compositions, fillers in different proportions and various types of hyperplasticizers.

An important factor in the preparation of self-compacting concrete is the optimization of the granular composition of cement. In the preparation of self-compacting concrete, it is mainly necessary to use finely ground cements with a particle size of 9-16 microns. When fine particles are lacking, the pores in the particle island are filled with water, as a result of which the properties of the mixtures, including their durability, decrease.

The compositions of the prepared concrete mixtures are given in Table 1. During the experiments, 10% of the mass of cement was added to the concrete mixture, and 5% of the mass of highly active metakaolin was added.

The mixture was placed in molds measuring 150x150x150mm to determine the strength limit, frost resistance and corrosion resistance. The hardening of self-compacting concrete samples occurred within 28 days under normal conditions. The compressive strength limit was determined after 7, 14 and 28 days. The test results of self-compacting concrete samples are given in Table 2.

The values shown in Table 2 are as follows: CA- composite adhesive; MS- microsilica;

For convenience, the batch numbers in Table 2 are indicated not by consecutive numbering, but by differences in composition.

Table 1.Concrete mix composition

Ingredients	Party number										
	1	2	3	4	5	6	7	8	9	10	11
	Unit of measure, kq/m^3										
CEM II/A-(P+L)-42.5	423	432	425	434	427	413	412	408	408	410	410
Guba sand	800	817	805	822	808	782	780	388	388	390	390
Bahrampepe sand	-	-	-	-	-	-	-	388	388	390	390
Guba crushed stone,5-10 fr.	720	735	725	740	729	702	701	694	694	698	698
Mikrosilika (MS)	-	43	-	43	-	41	-	41	-	-	-
Metakaolin (MTK)	-	-	21	-	21	-	21	-	21	-	-
Hyperplasticizer BETONMIX HP 1211A	-	4.3	4.3	-	-	-	-	-	-	-	-
Hyperplasticizer BETONMIX HP 1212	-	-	-	4.3	4.3	-	-	-	-	-	4.3
Water	292	252	249	254	250	307	302	306	306	306	226
Water/adhesive	0.69	0.53	0.56	0.53	0.55	0.67	0.69	0.68	0.71	0.74	0.55
Cone spread,mm	66	71	71	72	73	69	69	66	6	73	72

Table2.Physical and mechanical properties of self-compacting concrete

№	Additive name	Water/ adhesive	Medium density, kq/м^3	Compressive strength, MPa,(dat)			
				7	14	28	R/R_{con}, %
1	Control composition (CA+GS)	0.69	2344	20.8	36.0	38.6	100
6	CA+MS+GS	0.67	2344	25.5	31.0	34.6	89
2	CA+MS+GS BETONMIX HP 1211A	0.53	2374	38.5	51.5	52.9	137
	CA+MS+GS BETONMIX HP 1212	0.53	2374	34.2	50.2	56.6	147
7	CA+MTK+GS	0.69	2344	33.0	35.0	36.4	99
3	CA+MTK+GS BETONMIX HP 1211A	0.56	2359	39.1	51.7	53.0	137
5	CA+MTK+GS BETONMIX HP 1212	0.55	2374	38.6	54.2	57.8	150
8	CA+MS+BS/GS(50/50)	0.68	2325	29.1	33.8	36.0	91
9	CA+MTK+BS/GS(50/50)	0.71	2325	34.1	36.5	38.6	99
10	CA+ BS/GS(50/50)	0.74	2262	32.1	37.5	40.3	105
11	CA+ BS/GS(50/50)+ BETONMIX HP 1212	0.55	2362	36.3	54.0	60.1	156

The values shown in Table 2 are as follows: CA- composite adhesive; MS- microsilica; MTK- metakaolin; GS- Guba sand; BS- Bahramtepe sand; BS/GS (50/50) is the percentage ratio of Bakramtepe sand to Guba sand in the SCC composition; Water/Yap- water adhesive ratio.

In order to determine how the composition of the fine filler affects the strength properties of SCC, self-compacting concrete was prepared with various additives to the composite adhesive and fine filler additives of different compositions. The strength indicators of samples prepared only from Guba sand were compared with samples with a 50:50 percent ratio of filler composition to Bahramtepe and Guba sand. A comparison of the results of the two types of fillers is shown in Fig. 1 and 3.

MTK- metakaolin; GS- Guba sand; BS- Bahramtepe sand; BS/GS (50/50) is the percentage ratio of Bakramtepe sand to Guba sand in the SCC composition; Water/Yap- water adhesive ratio.

In order to determine how the composition of the fine filler affects the strength properties of SCC, self-compacting concrete was prepared with various additives to the composite adhesive and fine filler additives of different compositions. The strength indicators of samples prepared only from Guba sand were compared with samples with a 50:50 percent ratio of filler composition to Bahramtepe and Guba sand. A comparison of the results of the two types of fillers is shown in Fig. 1 and 3.

Fig. 1. shows a comparison of concrete mixtures of 6 and 8 batches. The results of both batches are almost close to each other. Both compositions contain microsilica as a mineral additive, differing only in the fine fillers. As can be seen, the compressive strength of batch 8 after 28 days is 2.2 MPa, i.e. 8% higher than that of batch 6. This is due to the dense arrangement of fillers in the concrete when using fine fillers.

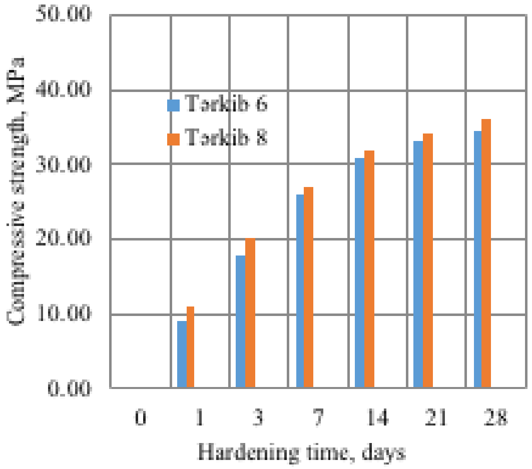

Fig. 1. Effect of fine filler type on the compressive strength of SCC (with MS addition)

When comparing Fig. 1 with Fig. 2, the composition of the concrete mix included mineral additives. However, in Fig. 3, when comparing batch 1 with batch 10, the composition of the concrete mix did not include mineral additives.

As in the compositions with mineral additives, the strength of the concrete increases when mixed fine aggregates are used even in the absence of mineral additives. In the composition 10, the compressive strength of the concrete after 28 days is 1.7 MPa higher than in the composition 1.

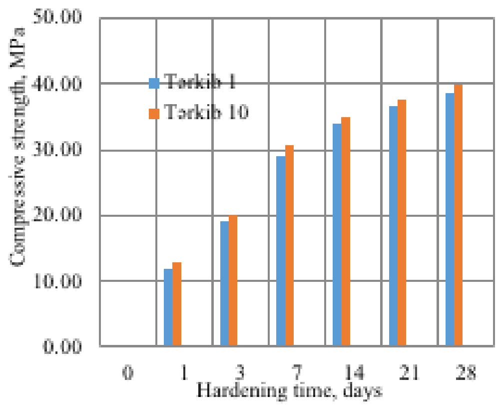

Fig. 2. Effect of fine filler type on the compressive strength of SCC (with MTK addition)

Fig. 2. shows a comparison of concrete mixtures of batches 7 and 9. Both batches are almost close to each other. Both compositions contain metakaolin as a mineral additive, differing only in the fine fillers. As can be seen, the compressive strength of batch 9 after 28 days is 1.4 MPa, i.e. 6% higher than that of batch 7. This is due to the dense arrangement of fillers in the concrete when using fine fillers.

Thus, regardless of the addition of mineral additives, the compressive strength of the concrete increases when mixed fine aggregates are used. This can be explained by the high coarseness modulus of Guba sand, and when Bahramtepe sand is added to it, the average grain size of the fine aggregate decreases, which allows for better compaction of the mixture and therefore we achieve higher strength indicators. It turns out that the lower the amount of large particles in the fine filler, the better it affects the strength of the concrete.

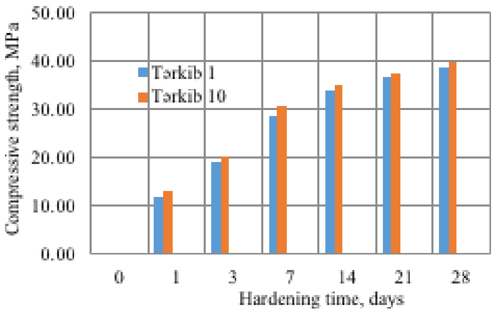

Fig.3. Effect of fine filler type on the compressive strength of SCC (without mineral additives)

Then, the effect of the composition of the composite adhesive on the strength of the concrete was studied. For this purpose, 2 groups of samples were prepared and tested: 1 group with an additive in the form of microsilica (composition 2, 4, 6) and 2 groups with an additive in the form of metakaolin (composition 3, 5, 7). Let's consider the results for concrete batches number 1 and 6. The composition of the concrete of the control batch number 1: CA + Sand (Guba) + Crushed stone (5-10 mm). The composition of the concrete of the batch number 6: CA + MS + Sand (Guba) + Crushed stone (5-10 mm). The concrete of the batch No. 6 differs from the batch number 1 only in that it contains an additive in the form of microsilica (MS). The compressive strength of the concrete of the batch number 6 is high only in the initial stages of hardening (7 days). However, the strength limits at 14, 21 and 28 days are higher for the control composition (batch number 1). That is, when microsilica is added to control batch number 1, the compressive strength of concrete decreases by 14%, which is proven in batch number 6.

Let's consider the results for concrete batches number 2 and number 4 relative to concrete number 1 (control batch). The composition of concrete of control batch number 1: CA + Sand (Guba) + Crushed stone (5-10 mm). The composition of concrete of batch number 2: CA + MS + Sand (Guba) + Crushed stone (5-10 mm) + Betonmix HP 1211A. Concrete composition of batch number 4: CA + MS + Sand (Guba) + Crushed stone (5-10 mm) + Betonmix HP 1212.

Considering the compressive strength indicators, we see that the distribution of strength for the concrete of these batches was as follows: number 4> number 2> number 1.

That is, when any of the hyperplasticizers was added to the mixture, the compressive strength of the concrete was higher than that of the control batch (without hyperplasticizer), regardless of the hardening time. Hyperplasticizer Betonmix HP 1212. From the results, it can be seen that composition number 4 is considered the most effective.

The effect of mineral additives in the form of MTK on the compressive strength of concrete was considered in concrete batches number 1 and number 7.

The composition of the control concrete batch No. 1: CA + Sand (Guba) + Crushed stone (5-10 mm).

The composition of the concrete batch No. 7: CA + MTK + Sand (Guba) + Crushed stone (5-10 mm).

The composition of concrete batch number 7: CA + MTK + Sand (Guba) + Crushed stone (5-10 mm).

Concrete batch number 7 differs from batch number 1 only in that it contains an additive in the form of metakaolin (MTK). As can be seen, the compressive strength of concrete batch number 7 is high only at the initial stages of hardening (7 days). However, the strength limits at 14, 21 and 28 days are higher for the control composition (batch number 1). That is, when metakaolin is added to the control batch number 1, the compressive strength of concrete decreases by 9%, which was proven in batch number 7.

Let's consider the results for concrete batches number 3 and 5 relative to the control batch number 1.

Concrete composition of control batch number 1: CA + Sand (Guba) + Crushed stone (5-10 mm).

The composition of concrete of batch number 3: CA + MTK + Sand (Guba) +

Crushed stone (5-10 mm) + Betonmix HP 1211A.

The composition of concrete of batch number 5: CA + MTK + Sand (Guba) + Crushed stone (5-10 mm) + Betonmix HP 1212.

Considering the compressive strength indicators, we can see that the distribution for the concrete of these batches was as follows: number 5> number 3> number 1.

That is, when any of the hyperplasticizers was added to the mixture, the compressive strength of the concrete was higher than that of the control batch (without hyperplasticizer), regardless of the hardening time. The results of the hyperplasticizer Stachement 2481 show that composition number 5 is considered the most effective.

Based on the data obtained, batch number 11 of self-compacting concrete samples was prepared and tested, which combined all the positive properties identified above, namely: the absence of a third mineral additive in the mixture, optimal distribution of fine aggregate particles, and the presence of a hyperplasticizer. As can be seen, the concrete of batch 11 has the highest compressive strength at the age of 28 days.

3. CONSOLUSIONS

- Analysis of the physical and technical properties revealed the differences between self-compacting concrete and conventional concrete. The physical and mechanical properties of self-compacting concrete depend on its composition, the ratio of materials, the type and amount of mineral aggregates, as well as superplasticizers.
- The effect of the composition of the fine aggregate on the physical and mechanical properties of the self-compacting concrete was evaluated. It was determined that the most optimal option for the fine aggregate is a composition containing a mixture of natural Guba and Bahramtepe sand mixed in a ratio of 50-50%. This option allows to increase the compressive strength of the concrete by 5-7.5%, when using only Guba sand as a fine filler.
- The addition of a superplasticizer to the composition of the adhesive cement increases the compressive strength of the concrete by 30%. When adding composition cement to the concrete mix, the formation of voids in the cement is practically impossible due to the arrangement of cement particles around the sand particles. Under the influence of the superplasticizer, the solution is saturated with water faster, and in addition, air bubbles are not observed when mixing the concrete mix.

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