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EXPERIMENTAL STUDIES OF THE STRENGTH OF FINE-GRAINED CONCRETE WITH IMPLEMENTATIONS OF ORGANOMINERAL ADDITIVES

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ABSTRACT

Experimental studies of the strength of fine-grained concrete with implementations of organo mineral additives were carried out. The organo mineral additive in the amount of 5-15% by weight of cement has a significant effect on the strength characteristics. Zeolite-containing rock with a specific surface area of 4000 cm^2/g was used in the studied compositions. The amount of water added to the mixture also increases with an increase in the amount of organo mineral additive in the concrete mixture. The introduction of an organo mineral additive as a mineral additive instead of a part of the cement promotes the pozzolanic process, in which amorphous silica (SiO2) is bound to the lime formed during cement hydration as a result of the transition to down-basic hydro silicates. The addition of zeolite-containing rocks in an amount of 5-15% by weight of cement has a significant effect on the strength characteristics. The greatest increase in compressive and flexural strength is achieved by replacing 10% cement with TPP ash (heat from a power plant). It was established that a 10% dosage of TPP ash is optimal and is used for a further selection of the composition of fine-grained concrete. The resulting mixture has increased workability and plasticity. The most optimal dosage of additives is 1-1.5%. As the second mineral additive, we used an additive of technogenic origin - microsilica, i.e. ash from burning rice husks. After studying the literature, it was concluded that the addition of microsilica in an amount of 10-12% by weight of cement most contributes to increasing the strength of concrete. The research work is aimed at improving the properties of cellular concrete, developing their composition and production technology by introducing minerals and modifying additives. The results of the research work provide an increase in manufacturability, strength, water and frost resistance, and operational reliability of the obtained materials. The joint implementation of ash and a chemical mixture into fine-grained concrete allows concluding that the strength indicators increase, and the water-cement ratio and porosity decrease.

Keywords: fine-grained concrete, frost resistance, modifying additives, cone flow, organomineral additive, silica fume, compressive strength, cement paste, ash.

INTRODUCTION

The usage of fine-grained concrete is economically feasible in many areas of the construction industry. The absence of high-quality coarse aggregate in the region, the presence of works requiring a reduction in aggregate size (such as the manufacture of thin-walled and densely reinforced structures), and the need for high strength and frost resistance are factors that contribute to the development of fine-grained concrete production. This type of concrete is distinguished by simple manufacturing technology, ease of transportation, and high physical and mechanical characteristics. Strict adherence to technology guarantees the production of concrete that is suitable for creating a wide range of products.

Along with the positive aspects, several disadvantages hinder the production of fine-grained concrete and its usage in construction. First of all, the disadvantages are due to the structure of concrete, which is characterized by: high uniformity and fine grain, high content of cement stone, lack of a rigid mineral aggregate, increased porosity, and specific surface area of the solid phase.

One of the effective ways to improve the quality of fine-grained concrete, as well as reduce costs in the production of concrete products, is the usage of mineral additives, which are finely ground mineral powders consisting of low basic silicates, calcium aluminates and ferrites, amorphous silica and other substances that have an independent hydraulic and pozzolanic activity. In combination with effective superplasticizers, mineral additives increase the strength of fine-grained concrete products, and reduce water demand and porosity.

The work is aimed at the development of compositions and technology for the production of fine-grained concrete by improving its properties, introducing minerals, and modifying additives. This provides an increase in manufacturability, strength, water and frost resistance, and operational reliability of the obtained materials.

Concrete is the main building material providing high bearing capacity and long service life [1]. The development of modern concrete science is aimed at improving the physical and mechanical characteristics of concrete, as well as at reducing costs in the production and operation of concrete and reinforced concrete structures. It is necessary to use innovative technologies in the production of concrete to implement these tasks [2].

Currently, one of the priority areas for the development of the building materials industry is the production of sand concrete and its products from them. Sand concrete is a common type of fine-grained concrete that does not contain coarse aggregates. The relatively high specific surface area of the aggregate in sand concrete causes an increased (by 20-40%) cement consumption, which is necessary to fill the intergranular pores and create a sufficient coating of the cement paste. The reduction in cement consumption is achieved by choosing the optimal granulometric composition of the aggregate, introducing active mineral additives and microfillers, the usage of superplasticizers ,and effective compaction methods.

The greatest strength of fine-grained concrete products is achieved with an optimal ratio between cement and sand (C: S). The quality of aggregate for fine-grained concrete affects its basic properties to a greater extent than ordinary heavy concrete. According to Yu. M. Bazhenov, the replacement of coarse sand in sandy concrete with fine sand can reduce the strength by 25-30%, and sometimes by 2-3 times. Both with optimal W/C and with the same workability of the mixture when using sand of medium size, the most economical compositions that provide the minimum ratio of cement consumption to concrete strength are achieved at C:S = 1:2-1:3. When transferring to fine-grained sands, compositions of 1:1-1:1.5 turn out to be optimal.

The quality of facing tiles and individual elements are studied in the given article. The properties of paving slabs were studied: water absorption (abrasion), the accuracy of geometric dimensions, appearance, compressive strength, and frost resistance in the experiments of the authors of this work. Work is underway to replace the elements contained in building materials with various wastes to solve urgent problems in the field of general construction. Let's look at the results of the various works examined as proof of it [3].

Worldwide, tons of waste from thermal power plants are annually exported. They occupy most of the natural lands and eventually pollute natural soils. Of these, it is possible to manufacture enclosing structures by adding waste from thermal power plants to the composition of crushed stone concrete. Waste burned in the open ground is different in terms of mineralogical, chemical, and granulometric composition, about 30% of which decomposes in atmospheric conditions. These circumstances upset the ecological balance in the world. The authors in their studies [4] showed that in order to add them to the concrete composition, it is necessary to grind from 0 to 5 mm. They presented the results of studies on the usage of fine-grained concrete M 50-150 (5-15 MPa) and concrete M 35-75 (3.5-7.5 MPa) for the bearing and enclosing structures of the base in the construction of two-story monolithic cottages [4].

The experiments were carried out on the analysis of high-speed deformations and violations of fine graining under tensile stresses in the next research work [5]. At the same time, they analyzed a number of works by foreign and domestic authors. Based on the analysis, conclusions were drawn about a number of specific properties, the properties of which have not been fully studied.

The authors in the following work used waste for concrete samples with five different rates, instead of sand: 10%, 20%, 30%, 40%, and 50% to replace fine aggregate (sand) in concrete. The tensile strength, bending strength, compressive strength and water absorption coefficient, and mechanical properties of concrete were determined in this composition. When replacing sand with waste, the compressive strength of concrete increases by 32%, tensile strength by 17%, and bending strength by 14% [6]. They found that with a volume of abrasive waste of 40%, the abrasive resistance of concrete increases by about 83%.

The sea shell is used as a fine aggregate in some studies [7]. The authors of the article in the experiments used the following contents: 10%, 20%, and 30% as a replacement for part of the sand. Compared to conventional sand concrete, the compressive and tensile behavior of concrete mixed with seashell aggregate was studied for 7 days, 14 days, and 28 days. When using crushed marine aggregate instead of 20% sand, the compressive strength of the concrete corresponds to the design strength of conventional M25 concrete at 35 N/mm2, and at 28 days of curing. It can be seen that the percentage increase in crushed sea bark radically reduces the strength of concrete as a result of the research.

The focus of attention for engineers and researchers in the field of public works is always choosing the right grinding mix for use in building materials. Reducing the porosity of dry and/or wet granular mixes is a major factor in the field of concrete preparation [8]. It should be noted the increase in strength while controlling the effect of porosity on the processing of wet granular mixtures. Therefore, the goal of the authors of this work [8] is to evaluate the porosity of dry granular mixtures and determine the optimal value of the fractal dimension (DF) with minimum porosity.

It is impossible to agree with the authors [9] that the construction sector is mainly responsible for the reduction of natural resources and environmental damage since the main activity of the construction industry is the extraction of minerals and careful storage of their main sources. The massive usage of concrete in connection with the development of various infrastructures has led to the excessive extraction of river sand from the riverbed. This has led to a number of detrimental effects on the ecosystem and resulted in a lack of quality raw materials.

The disposal of industrial waste and construction waste and the demolition of buildings is also urgent problems today. The authors [10] in this context considered the effectiveness of using various alternative fine aggregates (AFA) from different sources. For example, gravel sand (CRS), industrial by-products (IBM), and recycled fine aggregates (RFA). When used in concrete, the economic, environmental, and social benefits are increased. Literature reviews have shown the possibility that AFA can be replaced by natural fine aggregate in construction, but a comprehensive study of all their properties is needed. The authors agree [8] that AFA can be applied in the future to the composition of promising building materials. [10]

The amount of waste emitted from thermal power plants has risen sharply in the UK, which means higher taxes on landfill and causing great damage to the environment. Solving this problem requires flexible technology that efficiently processes and produces valuable energy. The authors note that one of the possible technologies is fast pyrolysis [11] with a combined heat

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and power plant. It is necessary to understand its economic characteristics to determine the feasibility of such a technology, in addition to technical details. This study presents an economic evaluation of a pyrolysis-TPP plant that processes three pretreated raw materials for energy recovery over a period of 20 years.

So far, scientists around the world have established that the active components of modern concrete are such active mineral fillers as micro silica, metakaolin, ash-containing or their composition, superplasticizers. The optimal combination of these modification mixtures allows to control of the rheological properties of concrete mixtures and changes the structure of the cement stone in such a way as to provide concrete properties that ensure the high reliability of structures. In this regard, the purpose of the research of the authors in this work [12] is to identify the effect of reactive powders used simultaneously with a colloidal surfactant on the strength of concrete and the rate of its formation. The experimental tests on compression, tension, bending, chloride penetration, and water absorption were carried out by them. The results show that with an increase in the replacement size of cement (Crushed granulated blast-furnace slag), (from 0 to 50%), the compressive and tensile strength decreases [12]. The maximum compression value and the optimal mixture composition were determined by solving this mathematical model after checking the compatibility.

Currently, there is no unequivocal opinion on which sand is best suited for the manufacture of fine-grained concrete structures. In accordance with the requirements of GOST 10268 - 85, all types of sands are used, and the fineness modulus of coarse-grained sands world ≥ 2.5. but the reserves of such sands are small, so fine-grained sands are used in large quantities. If fine-grained sands are used (1.5 ≤ Mcr ≤ 2.1), then cement consumption increases by an average of 5-10%, and when very fine sands are used (1 ≤ Mcr ≤ 1.5), cement consumption increases by 10-15 %. In addition, by 3-5%, dust-catching particles increase cement consumption by another 3-5%. 65.5% of the total consumption of cement leads to a decrease in the quality of the filler, 22.5% cause a change in the heat treatment mode, and only 12% determines the properties of used cement.

Therefore, the role of the large-scale composition of sands is very important when the putty is used as a filler in concrete, and it is not surprising that much attention is paid to the issue of improving its functional composition [13]. After examining the effect of sand coarseness on concrete quality, many scientists have drawn different conclusions: one states that continuous sand granulometry is effective, and the other states that sand with better granulometry can be obtained with maximum average density.

N. P. Aleksandrin, M. A. Popov, and B. G. Skramtayev consider that continuous sand granulometry is effective, since it brings such sands closer to natural sands, and their usage is economic. It was decided that fine sand fractions can compensate for the consumption of cement and ensure the necessary contact of the concrete mixture. At the same time, if natural sands are very strong in composition, then it is more profitable to introduce coarse-grained sands and microwaves into them [14-18].

S. A. Weymouth stated that the granules of each small fraction should act as large granules. The deviation from the optimal granular composition affects the consumption of cement and the strength of crushed concrete.

Natural sands are used in an under-fractionated form, however, the usage of washed classification sands reduces cement consumption and increases the strength of crushed stone concrete.

In many studies, studying the effectiveness of the granular composition of sand, it was found that the usage of fractionated sands in fine-grained concrete reduces the consumption of cement, and increases crack resistance and the viability of the product. This is due to the fact that it is possible to achieve the best set of granules - high density or maximum cavities by changing the granular composition of the sand. There is a lot of data proving the tricks of scientists based on the determination of the granular composition of the sands.

R. Fere came to the conclusion that the greatest strength and density of the sand mixture in sands with a ratio of 2: 1 fraction of 2 - 5 mm and 0 - 0.5 mm.

The maximum density of sets of fillers V.V. Okhotin and G.S. Khovansky can be achieved in the ratio d:d = 16:1 of fine-grained and coarse-grained diameters [19-20].

T. Yu. Lyubimova recommends using sands with a particle size of mir ≥ 2.5 in crushed stone concrete, while the coarse-grained composition of 5-1.25 mm should be at least 50, and the fine-grained composition, which acts as a microwave, must be 10. Fraction fluctuations within 30-50 do not affect cement consumption at all. The cement consumption can be reduced to 80–140 km/m^3 on the correct choice of sand [21].

V. A. Voznesensky proposed to investigate the sands as a mixture of four fractional granules: large No. - 5-1.2 mm; medium No. 1-1.2-0.6 mm; medium No. 2–0.6 - 0.3 mm; in oil-0.3-0.15 mm.

He found that the sands of the average fraction of 40% and in the ratio of 1-2 2: 1 have the smallest void. The optimality of unorganized granulometric sands makes it also possible to reduce cement consumption by 10–20% in this fine-grained concrete [22-23].

The elimination of the average fraction of 0.3-1.2 mm and the creation of optimal amounts of granules of fractions of 0-0.15 mm and 1.2-5 mm allowed A.A. Shadrin to reduce the strength and density of cellular concrete. R.P. Burangulov found that the maximum density and strength of cellular concrete can be achieved in the ratio of fractions by weight of 0:3:0.7.

- More studies showed the high efficiency of the usage of crushed stone concrete, specially prepared for the granulometric composition.

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MATERIAL AND METHODS OF THE RESEARCH

Portland cement from the Shymkent plant was used in the experiments. The chemical and mineralogical compositions of the cement of this plant are presented in Tables 1 and 2.

Table-1. Mineralogical composition of cement.

Name of the cement	C_3S	C_2S	C_3A	C_3AF
Portland cement M-400	57-62	14-18	5.5-7.5	12.5-15

Table-2. Chemical composition of the cement.

Name of the cement	An amount of oxides, %							
	SiO_2	Al_2O_3	Fe_2O_3	CaO	SO_2	MgO	P_2O_5	LOI
Portland cement M 400	22,35	4,49	4,63	66,01	0,81	1,23	0,2	0,75

As a silica component, a local building material was used barchan sand of the Tas-Buget deposit

Table-3. Particle size distribution of barchan sand.

Name of deposits	Residues on the sieve	Cell size piece, mm						Passed through the sieve
		5,0	2,5	1,25	0,63	0,315	0,14	0,14
Tas-Buget (Kyzylorda region)	private	0	0	0	0	0,5	48,3	51,2
	complete	0	0	0	0	0,5	48,3	100

Table-4. Physical characteristics of barchan sand.

Name of the studied factors	Kyzylorda (barchan sand of the Tas-Buget deposit)
Bulk density, kg/m^3	1350
Void, %	48,9
true density, $п/cm^3$	2,64
Size module, M_k	0,49
Specific surface area, cm^2/g	365
Loss of mass during elutriation,%	1,3
Calometric test	lighter than standard

Table-5. Chemical composition of barchan sand.

Name of the sand	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	K_2O	LOI
Tas-Buget (Kyzylorda region)	9,05	73,6	5,56	1,99	1,0	1,9	6,9

Table-6. Mineralogical composition of barchan sand.

Name of deposits	Mineral content,%		
	Quartz	Feldspar	Carbonate
Tas-Buget (Kyzylorda region)	63,7	14,6	21,7

In addition to mineral raw mixtures, the superplasticizer C-3, a condensation product of naphthalene sulfonic acid and formaldehyde, was used in the experiments. The plasticizer C-3 was used to increase the workability and formability of concrete mixtures. And also for a significant increase in the physical and mechanical properties and construction and technical properties of concrete (with a reduction in water consumption and unchanged workability) [24];

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It is known that fine-grained concrete has increased flexural strength, water resistance, and frost resistance.

To determine the strength of fine-grained concrete, due to the lack of large aggregates, it is rational to use samples of smaller sizes than conventional ones: cubes 3x3x3 cm, 5x5x5 cm, 7x7x7 cm and beams 4x4x16 cm (as when testing cement).

The smaller size and increased specific surface of sand increase the water demand of the concrete mixture, contributing to the entrainment of air into the concrete mixture during vibration. The water demand of the cement-sand mixture is determined not only by the required mobility but also by its composition.

The consumption of water and cement increases by 20-40% compared to ordinary concrete as a result of obtaining equal-strength concrete and equally mobile concrete mix in fine-grained concrete. Chemical additives, and effective compaction of sandy concrete mixtures and coarse sands with an optimal grain composition should be used to reduce cement consumption. It is useful to use plasticizers, superplasticizers, and organomineral additives in cement-sand mixtures with a high content of cement.

The compaction of the cement-sand mixture was carried out by pressing, tamping, and vibrating with weight.

Fine-grained concrete movability tests were carried out on small-sized samples. The movability of the concrete mixture can be determined by the time the cone floats on a shaking table, as when testing cement in a plastic mortar, by workability when vibrating a small cone (h = 10 cm), in the form of 10x10x10 cm, after the mixture flows out of a small cylinder, by immersing the cone. The shaking table test evaluates the movability of fine-grained mixtures with a greater degree of accuracy than other methods.

It is necessary to know the effect of the concrete composition and the quality of the raw materials on the movability and workability of the cement-sand mixture when determining the composition of fine-grained concrete.

The movability of the cement-sand mixture is determined by the content of the cement paste and its consistency, which depends on the water-cement ratio. This dependence can be represented as the dependence of the cone flow on the C/S and W/C ratios (Figure-1).

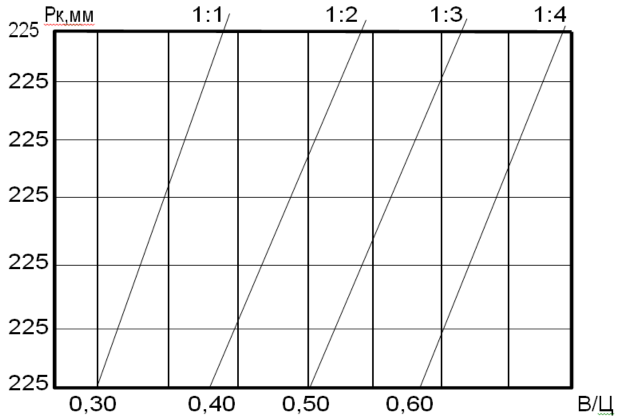

Figure-1. Graph of the ratio between cement and sand, which provides a given spread of the cone Pk at a certain W / C.

The quality of the sand will affect the cone flow with a decrease in the size of the sand and an increase in its specific surface, the water proportion increases, and the movability of the mixture decreases. It is required to increase the water consumption or the water-cement ratio at a constant C/S, or increase the C/P at a constant W/C required to obtain a given concrete strength in order to obtain equally mobile cement-sand mixtures [25, 26].

The concrete mixture was prepared with the addition of technogenic origin - ash from the Kyzylorda TPP and the additive – micro silica from rice husk ash, as well as without additives to study the properties of fine-grained concrete with mineral additives. The components of the mixture were cement CEMI-32.5N produced by “Standardcement” LLP, the city of Shymkent, barchan sand of the Kyzylorda deposit, and also superplasticizer C-3.

The strength of concrete samples for bending and compression was determined on samples - beams 4x4x16 cm in size. A composition of 1:3 was chosen as a control composition.

The graphs of the strength development of the control composition and compositions with an organomineral additive are shown in Figures 2 and 3.

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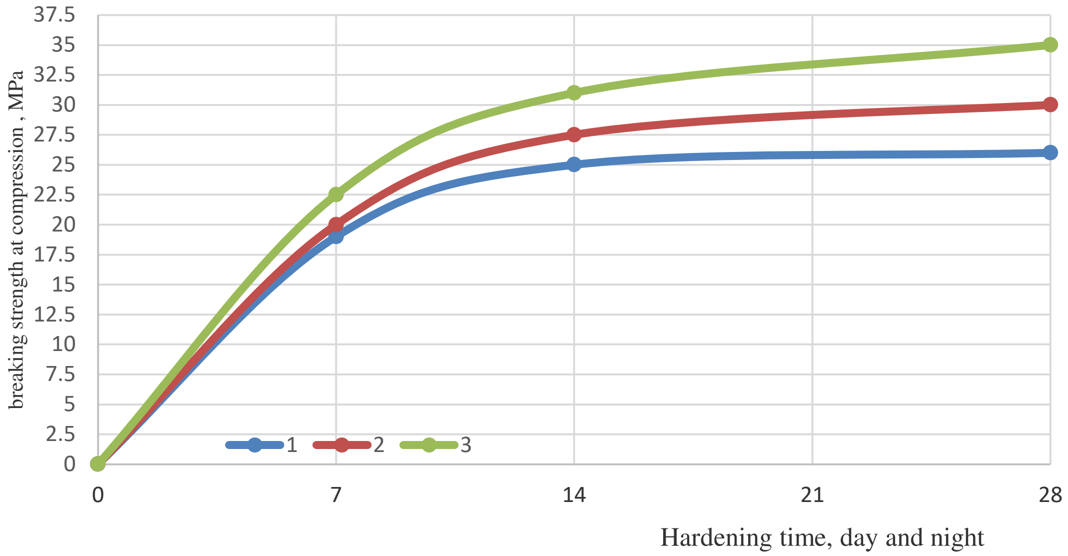
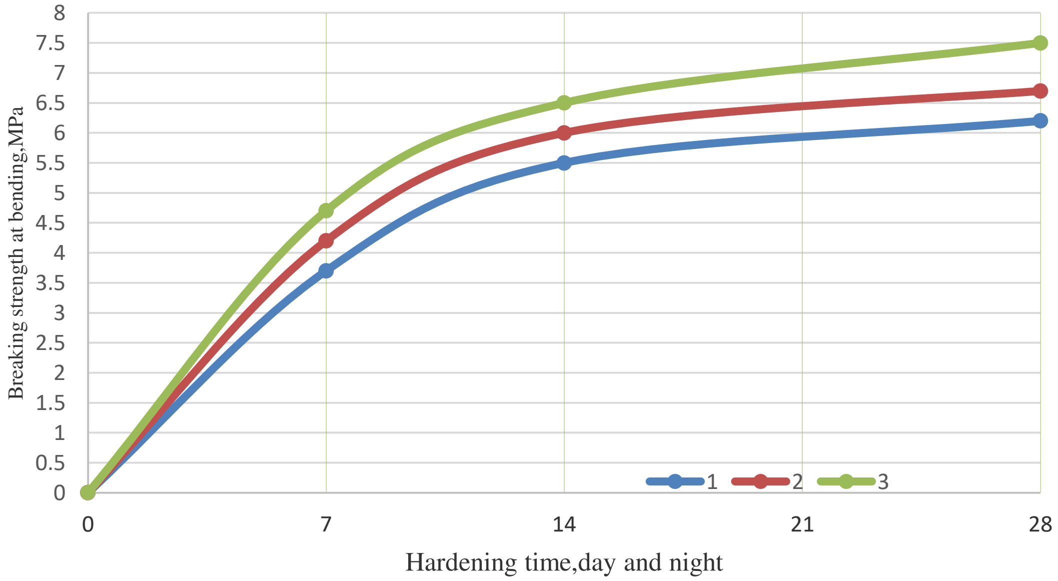


1 - control composition, 2 - organomineral additive 5%, 3 - organomineral additive 10%.

Figure-2. Influence of organo-mineral additives on the compressive strength of fine-grained concrete.



1 - control composition, 2 - organomineral additive 5%, 3 - organomineral additive 10%.

Figure-3. Influence of organo-mineral additives on the strength of fine-grained concrete at bending.

It can be judged that the organomineral additive in the amount of 5-15% by weight of cement has a significant effect on the strength characteristics as a result of the obtained data. Zeolite-containing rock with a specific surface area of 4000 cm^2/g was used in compositions No. 2 and No. 3.

The amount of water added to the mixture also increases with an increase in the amount of organomineral additive in the concrete mixture. This is due to the fact that the finely dispersed ash of thermal power plants has a high adsorption capacity.

The implementation of an organomineral additive as a mineral additive instead of a part of the cement promotes the pozzolanic process, in which amorphous silica (SiO2) binds to lime formed during cement hydration as a result of the transition to low-basic hydro silicates. The cement stone structure is compacted with fine particles that fill the space between the particles in the cement paste and the hydration product in the cement stone, which in turn leads to an increase in the strength of fine-grained concrete.

RESULTS AND DISCUSSIONS

It can be judged that the addition of zeolite-containing rock in an amount of 5-15% by weight of cement has a significant effect on the strength characteristics as a result of the obtained data. Ash from the Kyzylorda TPP with a specific surface area of 3000 cm^2/g was used in compositions No. 2 and No. 3, 4.

The amount of water added to the mixture also increases with an increase in the amount of TPP ash in the concrete mixture. This is due to the fact that the zeolite-bearing rock has a high adsorption capacity.

The implementation of TPP ash and micro-silica as a mineral additive instead of part of the cement contributes to the pozzolanic process, in which amorphous silica (SiO2) binds to lime formed during cement hydration as a result of the transition of a too-low basic hydro silicate. The structure of the cement stone is compacted with fine particles, filling the space between the particles in the cement paste and the hydration products in the cement stone, which in turn leads to an increase in the strength of fine-grained concrete.

The greatest increase in compression and bending strength is achieved by replacing 10% cement with TPP ash. We consider this dosage of TPP ash to be optimal and use it in the further selection of the composition of fine-grained concrete.

CONCLUSION AND OUTCOMES

It can be concluded that the joint implementation of the ash of the Kyzylorda TPP and a chemical additive into fine-grained concrete increases the strength characteristics, and reduces the water-cement ratio and porosity based on the results of the obtained data. The resulting mixture has increased workability and plasticity. The most optimal dosage of additives is 1-1.5%.

We used an additive of technogenic origin-micro-silica, i.e. ash from burning rice husks as the second mineral additive. It was concluded that the addition of micro-silica in an amount of 10-12% by weight of cement most contributes to increasing the strength of concrete after studying the literature. Micro-silica binds free calcium hydroxide into low basic calcium hydro silicates, resulting in increased strength. We consider the dosage of micro-silica equal to 10% to be optimal and use it in the further selection of the composition of fine-grained concrete.

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