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Influence of mineral additives on the performance properties of self-compacting concretes in the production of reinforced concrete products

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Abstract. From the point of view of solving the problems of implementing resource-saving technologies in the construction industry, the issue of the efficiency of self-supporting concrete mix compositions occupies one of the leading places. The paper considers the impact of introducing common mineral fillers into self-supporting concrete mixes as one of the ways to improve the rheological characteristics, environmental friendliness and economy of this type of concrete from the point of view of practical application. The paper considers 3 types of mineral additives, from the well-studied mcu of microsilicon and mcl of metakaolin to opalo-chalcedony flask, which were not tested in the composition of self-supporting concretes. Test results improved rheological parameters of the concrete mix when replacing part of the cement with mineral dobaka to optimal values for viscosity and system performance, as well as increased frost resistance of concrete Fup to F 300, reduced volumetric water absorption of concrete up to 30%, reduced shrinkage deformations when using mineral mixtures in this type of concrete - 0.07-and confirmed the possibility of demotion. For ease of use, the test results are presented in the form of visual graphs and tables.

Keywords: *frost resistance, water absorption, heat shrinkable deformations, mineral additives, cement, self-supporting concrete.*

1. Introduction

Over the past century, many important discoveries and implementations have been made to address the challenges of energy-efficient production and the introduction of technologies that contribute to creating energy-efficient redistributions in concrete production technologies. However, with the development of the construction industry, the need to increase and accelerate production increases, which currently scientists have to simultaneously solve environmental issues and savings in the production of efficient building materials [1].

To date, it has been proven that the introduction of mineral mixtures as an independent component of concrete mixtures3 is one of the most important ways to increase the economic efficiency of cement compositions at the cost of 1 m3 of concrete and cement consumption, as well as to improve their construction and technological properties [2].

Mineral additives for concrete production are widely used in foreign practice, primarily for high-performance concretes, including self-supporting concretes. At the same time, self-supporting concretes (PTO) are widely introduced into the world experience of monolithic and factory technologies for manufacturing general construction structures. The use of PTO provides comprehensive economic efficiency: the ability to avoid vibration and heat treatment in the production of reinforced concrete products and structures, reduce viscosity, increase the uniformity and strength of concrete, save labor, low costs for repairing technological equipment, and improve working conditions. In addition, the use of natural and man-made mineral fine fillers, which reduce the consumption of cement in concrete, reduces the degree of anthropogenic impact of its production on the atmosphere.

One of the main conditions for the application of economic efficiency, environmental cleanliness of production and self-supporting concrete in the world practice is the use of local raw materials base of mineral mixtures. In this context, the study of various types of natural and man-made mineral raw materials characteristic of different regions of Kazakhstan is a very urgent task for their application in these concretes [3].

In general, the introduction of active mineral additives in cement systems allows creating the necessary rheological conditions for obtaining high-tech and convenient mixtures, forming a tightly packed material structure and, accordingly, the strength of the conglomerate. The increase in the strength of cement composites with an optimal degree of filling with mineral powders is explained by the oriented effect of their grains on the cement hydration products and the formation of cluster structures, the use of materials closes to each other in crystal-chemical structure, the formation of additional bonds as a result of chemical interaction of components when introducing pozzolan mixtures, and a decrease in porosity. Considering the variety of components of highly functional concretes and the variability of raw materials used in them, additive, synergistic, superpositional, and antagonistic effects are possible [4].

Microsilicon is well studied as a fine mineral filler-a modifier of highly functional concrete. In addition, a number of pozzolanic and inert fillers, namely metacaolin, flask, zeolites, are poorly studied. In addition, the properties of this natural raw material can vary significantly depending on the deposits.

It is known that the activity of metakaolin in the Cement-water system is due to the presence of silicon dioxide and alumina in their composition. The reactivity of pozzolan in natural flasks is associated with meta-constancy, mainly due to the chemical and mineralogical composition, and to a lesser extent due to the brittleness of grinding [5].

The purpose of this research work was to develop the composition of medium-strength self-supporting concretes with improved rheological and operational characteristics for technological lines for the production of high-quality reinforced concrete products. To achieve this goal, a study was conducted on the influence and interaction of three popular mineral modifiers in filled cement systems; the estimated amount of the mineral component of the concrete mix was determined by studying and identifying factors that affect the formation of a tightly packed material structure and, accordingly, the improvement of operational characteristics. The increase in the density of cement composites at the optimal degree of filling with mineral powders is explained by a number of factors: the directed action of their grains on the products of cement hydration and the formation of cluster structures, the use of materials that are close to each other in crystal-chemical structure, the formation of additional bonds as a result of chemical interaction of components

In laboratory conditions, a class composition of 30/35 PTO strength was experimentally obtained, then it passed a number of production tests and was adopted into the technological process for the production of reinforced concrete products of complex geometric shapes.

2. Materials and methods

The research was conducted in 5 stages, each of which is aimed at solving specific tasks:

- stage 1: selection of the main materials for conducting the study in accordance with the regulatory documents of these materials;
- stage 2: calculation and selection of the control composition of samples of self-compacting concrete solutions;
- stage 3: introduction of the estimated amount of 3 popular types of mineral mixture and determination of the main rheological indicators;
- stage 4: selection of the control composition of self-compacting concrete of the main class used in the production of c 30/35;
- stage 5: testing of concrete samples for reliability of operation, frost resistance and volumetric water absorption, checking by measuring shrinkage deformations at the age of 28 days;

Calculations were made using the method of selecting the composition of self-charging concrete mix based on the method of the founder of the Japanese PTO-X. Okamura. This relatively simple method was developed by Professor Hitoshi Okamura (Okamura), University of Tokyo in the 90s of the 20th century [9].

The method was developed for the purpose of designing VET:

- with a high fine fraction content.
- the size of a large unit is 5-20 mm.
- use of medium-grade portland cement;
- the air content is 4-7%.

Step 2.1. Description of the materials used:

Table 1 shows the characteristics of a viscous substance (cement) adopted in accordance with [10].

Table 1. Characteristics of cement

Brand of cement	Manufacturer	Compressive strength of at least 28 days, MPa	Start of installation, at least, min	Consumption of heavy concrete per 1^{m3}, kg
CEM I 42.5 N *	Heidelberg Cement, LLP (Shymkent, Kazakhstan)	47.2	124	400-550

* [10] the following value of CEM I 42.5 N is given: I-denotes the first type of gypsum composition (according to SO_3), which should not be lower than 1.5% and not higher than 3.5-4.0% (for high-strength immiscible cements); 42.5-minimum standard compressive strength denotes the strength class corresponding to it value; N indicates a class with normal strength at an early age.

Table 2 shows the chemical composition of Cem I 42.5 N.

Table 2. CEM IMass fraction of CEM I 42.5 N, % [11]

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	Other supplements
22.10	3.85	4.76	62.99	3.55	0.75	0.7	0.42	0.88

To confirm the compliance of the selected viscous substance with the standards and requirements, a number of tests were carried out. Methods [10] and [11] given in the standards allow us to determine the following parameters:

1) fineness of grinding:

The tested viscosity showed a fineness of 92.9%.

2) normal density and setting time of cement dough:

The test viscous substance showed a normal thickness of 26.8%. The beginning of abstinence occurred 2 hours and 4 minutes after the approvalамдылық of the end of abstinence in 4 hours and 24 minutes. The obtained indicators correspond to [10] and [11].

Sand produced by Mark LLP (Almaty region, Kazakhstan) was used for testing. This filler meets the requirements of the standard [13]. Table 3 shows the characteristics of the used fine aggregate (sand).

Table 3. Characteristics of sand

Sand Group	Manufacturer	Grain size, mm	Total residue in the sieve No 063, %	Amount of dust and clay mixtures, %	Consumption of heavy concrete per 1^{m3}, kg
large	Mark, LLP (Almaty, Kazakhstan)	2.5	64.1	1.38	800-1000

To obtain satisfactory characteristics of the concrete mix and concrete, sand should be used in which the amount of pulverized impurities does not exceed 1.5%. The content of dust and clay compounds in the studied sand was 1.38%. The sand under study had a powdery modulus of 2.5. These parameters are favorable for the use of the aggregate under study in heavy concretes [13].

For large-sized aggregate of heavy concrete (crushed stone and crushed stone) [19], in order to obtain satisfactory characteristics of the concrete mixture, the total residues on control sieves when sowing fractions of 5-10 mm, 10-15 mm, 10-20 mm, 15-20 mm, 20-40 mm, 40-80 mm and mixtures of fractions of 5-20 mm must correspond to those indicated in Table 4, where d and D- the smallest and largest nominal grain sizes in mm.

Table 4. Recommended seeding rates for large aggregates [14]*

Diameter of holes of control sieves, mm	Total waste in the sieve, % by weight
d	From 90 to 100
0.5(d+D)	From 30 to 60
D	Up to 10
1.25D	Up to 0.5

* Gravel fractions of 5-10 mm and gravel are additionally used for mixtures of fractions of 5-20 mm: the bottom sieves should be 2.5 mm (or 1.25 mm), the total residues of which should be from 95% to 100%. By agreement of the manufacturer with the consumerгравий, it is allowed to prepare from 30% to 80% by weight of gravel and gravel with a total residue on the screen of 0.5 (d+D) [14].

Crushed stone of 5-10 mm and 10-20 mm fractions produced by Kentas LLP (Almaty, Kazakhstan) was used as a large aggregate. This filler meets the requirements of the standard [15]. Table 5 shows the characteristics of the large aggregate (crushed stone) used.

Table 5. Indicators of large roofing companies

Granule size mm	Manufacturer	Total waste in the sieve 0.5 (d+D), % (norm 30-60)	1.25 D total sieve residues, % (the norm is not more than 0.5)	1 м^3 PTO consumption 1 m3, kg
5-10	Kentas, LLP (Almaty, Kazakhstan)	55.77	0.44	200-400
10-20		54.31	0.37	500-700

Table 6 shows the characteristics of the micro filler (microsilicon), adopted in accordance with [16].

Table 6. Microsilica Characteristicsof monosilicon

Stamp	Manufacturer	Mass fraction of active SiO2, wt%, not less than 95	Consumption of heavy concrete per 1^{m3}, kg
K-95	Tau-Ken Temir LLP Karaganda, Kazakhstan	96.85	up to 50

Microsilicon contains spherical particles with a diameter of 0.1 microns and a specific surface area of 15-25 g/m^2 and above. The density of the embankment varies from 150 to 250 kg/m^3. By chemical composition, silicon is mainly non-crystalline microsilicon, the composition of which usually exceeds 85 and reaches 98%. According to Tau Kun Temir LLP, Karaganda, Kazakhstan, the capacity is about 3.980km^2/g [17].

Table 7 shows the chemical composition of microsilicon, adopted in accordance with [16].

Table 7. Chemical composition of Microsilicon MK-95,%

SiO_2	C	Humidity	Fe_2O_3	Al_2O_3	CaO	pH value	p, g/cm3^3	P. P. P.
96.85	1.31	1.07	0.07	0.24	0.46	7.89	0.44	1.68

When compared with the quality standards of microsilicon [16], the content of oxides in microsilicon from the chemical composition recommended by the manufacturer is sufficient to obtain results in the tasks set.

Based on the experience described in [12], the flask of the Shilovsky field in the West Kazakhstan region was accepted as the next micro-filler.

Opalo-chalcedony deposits of this deposit are represented as globules and Spicules in the vast majority of amorphous silica, sea sponges, radiolarians, shells, etc. The characteristics of flask produced at the Shipovsky field in the West Kazakhstan region are shown in Table 8.

Table 8. Description of Shipovsky field flask definition

Indicator	KValue of the K indicator		
	Minimum	Maximum	Average
Specific gravity, N / m3^3	22.27·10^3	24.13·10^3	23.15·10^3
Density (in section), kg / m^3	1050	1665	1240
Water absorption, %	15.34	41.00	25.00
Compressive strength, Mpa, in the state of:			
Dry	6.239	14.09	9.49
Saturated with water	44.9	11.47	6.61
Frost resistance	25	37	31

The flask of this deposit has the following chemical composition (Table 9).

Table 9. Chemical composition of the Shipovsky field flask

In the p component	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3
Flask	87.02	10.58	3.84	4.73	2.45	1.90

In comparison with the requirements of the chemical composition of the flask of the Shilovsky deposit [38], the content of basic oxides in the flask is sufficient to obtain results in the tasks set.

The flask accepted for testing is pre-milled on a BS-BALLMILL-I laboratory ball mill with a rotation range of up to 200 rpm to a specific surface area of 1700-1850 cm^2/g.

[20] metakaolin MKZHL, a producer of Plast-Rifey LLC, was accepted as the third mineral additive. According to the manufacturer, the mineralogical composition of METAKAOLIN MCG is represented by completely amorphous kaolinite (90-93%), relic mica of the crystalline phase (2.5-3.0%) and quartz (4-5%), crystal growths (mullite, kristabolite) are practically absent.

Metakaolin MCJD has the following chemical composition (Table 10).

Table 10. Chemical composition of metakaolin MCGD

	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	K_2O	Na_2O	CaO	PPP
Size, %	42.5	53.5	0.6	0.4	0.9	0.05	0.15	up to 1.5

The mainfeature of metakaolin microsilicon is its chemical nature. Unlike microsilicon, metacaolinis a mixture of active silica and aluminum oxide, in approximately equal proportions, that is, aluminum silicate, and not pozzolan. In combination with the use of highly effective plasticizers, metakaolin can significantly reduce the cement content in concrete formulas, especially in concretes with high water resistance and frost resistance. Experience shows that at a dose of 2% to PC, metakaolin significantly increases the waterproofness of the obtained compounds. According to [21], the aluminum component of metakaolin is able to actively interact with gypsum in Portland cement or is attached to special cement compounds.

Based on the previous studies indicated in the data [22], an additive based on polycarboxylate ether AR 122 produced by ARGP LLP in Astana was adopted as a plasticizing additive.

The Table 11 shows the characteristics of the chemical mixture (hyperplasticizer polycarboxylate PCE) adopted in accordance with [23] PCE.

2.2 stage. The choice of composition was made according to the method of Professor Okamura, provided that the usual concrete mix is proportional, the water-cement ratio is initially fixed in terms of obtaining the necessary strength, in self-compacting concrete, the ratio of water and binder should be determined considering that it is self-supporting, since the self-compaction of the concrete mix is very sensitive to this ratio. In most cases, the required strength does not determine the water-cement ratio, because if most of the mineral additives used are not reactive, the viscosity of water is small enough to obtain the required strength for conventional structures. Self-supporting concrete mortar must have a high viscosity, as well as high deformation. This can be achieved by using a superplasticizer that provides a low water permeability ratio under high deformation [34]. The ratio of the volume of large aggregate to its solid volume (G/Glim) for each type of concrete is shown in the Figure. 1. The packing rate of large aggregate in SCC is about 50%, to reduce the interaction of large aggregate particles when concrete is deformed. In addition, the same figure shows the ratio of fine filler volume to solid volume (S/Slim) in solution. The degree of fine aggregate winding in the SCC solution is about 60%, so when concrete is deformed, the SDV deformation can be limited (Figure 1).

Table 11. PCE Characteristics of the PCE Polycarboxylate hyperplasticizer

Stamp	Manufacturer	Mixture efficiency criterion	Consumption of heavy concrete per 1^{m3}, kg
AR 122	TOO «ARGP LLP, Astana, Kazakhstan	from P1 to P5	from 7 to 15

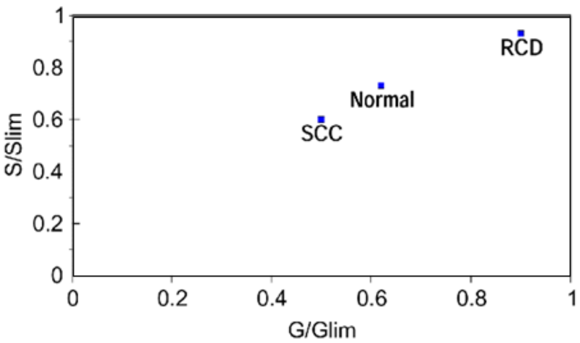

Figure 1. Degree of aggregate compaction-large aggregate in concrete and small aggregate in mortar [9]

SCC-self-supporting concrete
Normal-ordinary concrete
RCD - Roller Compacted concrete for Dams

Then, based on the conditions proposed by Professor Okamura, we choose the size of a large unit. The composition of the large-sized unit салмағының 50% мөлшерінде is set in volume density in the amount of 50% of the mass of the large-sized unit.

1500 kg/m^3 if the density is in a dry, compacted state, 1500 kg/m^3. The content of a large aggregate: 1500x0.5 = 750 kg.

In this case, a coarse-grained aggregate > 4.75 mm is used as a large aggregate.

- calculation of the composition of a small aggregate. The composition of the fine aggregate is set in the amount of 0.6 of the total components of the solution.

As a fine filler, a material with a grain size from 4.75 to 0.09 mm is accepted.

Composition of the small unit: 1500x0.6 = 900 kg.

To further determine the characteristics of materials used in self-compacting concrete, such as viscous material, sand, and superplasticizer, the viscosity of the solution is tested as time flowing through the funnel. The deformation properties of the solution are also tested to determine the opacity of the cone.

2.3 stage. A number of tests are carried out to determine the turbidity of a cone with an initial water-to-viscosity ratio of 0.4 and various doses of mineral additives and superplasticizer. Obtaining a mixture of water, viscosity, and superplasticizer showing cone blurriness of 244-246 mm during the test, the end time is 9-11 seconds through the funnel [9]. Next, a laboratory test of the rheological properties of the obtained compositions is carried out to fully calculate the components of the concrete mixture and prove its successful selection. 3 generalized data on the rheological properties of solutions using various amounts of mineral mixture are given in Tables 12,13,14.

Table 12. Influence of the amount of microsilicon mixture MCU on the rheology of the cement-sand mixture

№	Main team*	Cement, kg	The amount of microsilicon from the cement mass, %	Superplasticizer size, kg	Blur (mm)	Drain time, sec
1	Sand-900 kg, Water-cement 0.4	600	0	12	265	
2		570	5	11.4	261	
3		540	10	10.8	253	
4		510	15	10.2	245	0
5		480	20	9.6	237	2
6		420	30	8.4	231	4

* all data 1 m^3 are provided based on the number of components per 1 m^3 of concrete or mortar mix

Table 13. Influence of the amount of flask mixture on the rheology of the cement-sand mixture

№	Main team**	Cement	Number of flasks from the cement mass, %	Superplasticizer size, kg	Blur(m)	Drain time, sec
1	Sand-900 kg, Water-cement 0.4	600	0	12	265	7
2		570	5	11.4	246	9
3		540	10	10.8	232	12
4		510	15	10.2	227	14
5		480	20	9.6	213	17
6		420	30	8.4	205	20

* all data 1 м^3 are provided based on the number of components per 1 m3 of concrete or mortar mix

Table 14. Effect of the amount of metacaolin mixture on the rheology of the cement-sand mixture

№	Main team**	Cement	Number of flasks from the cement mass, %	Superplasticizer size, kg	Blur(mm)	Drain time, sec
1	Sand-900 kg, Water-cement 0.4	600	0	12	265	7
2		570	5	11.4	251	8
3		540	10	10.8	245	9
4		510	15	10.2	240	11
5		480	20	9.6	232	13
6		420	30	8.4	225	15

* all data^3 are provided based on the number of components per 1 m3 of concrete or mortar mix

From the tables reflecting the rheological characteristics of the obtained solutions, it can be seen that with the minimum consumption of expensive hyperplasticizer, the best effect is achieved by replacing 15% of cement with MICROSILICON MCU.

Then, after 1 day and 28 days after mixtures of solutions showing the values required for cone diffusion and leakage [24], samples tested for appropriate compressive strength were formed through a funnel. The test results are shown in Table 15.

Table 15. indicators of compressive strength of samples of solutions with microsilicon MCU, protection O and metakaolin D MCU aged 1 and 28 days

№	Cement	Filler size, %	Filler size, kg	Strength indicators (MPa)							
				MCU-1day	MCU-28days	O-1day	O-28The sun	KZHL-1solnce	QOL-28 days	K-1	Without additives -28
1	600	0	-							1.2	7.7
2	570	5	30			1.5	38.1				
3	540	10	55		-		-	12.5	1.5		
4	510	15	80	12.8	0.7	-	-		-		

The strength characteristics of the solution samples show that the best effect is achieved by replacing 10-15% of microsilicon MCU cement and METAKAOLIN MCL.

2.5 stage. Further, based on the obtained data on the deformability, viscosity and compressive strength of mortar compositions according to the principle of Professor Okamura's choice [9], the optimal composition of self-compacting PTO concretes with three types of mineral mixtures was calculated, for which summary data are given in the table.

Table 16. VET composition

# composition	S/C	Cement, kg/m3[3]	Mineral supplement	sand, kg / m3[3]	Crushed stone, 5-10 mm, kg / m3[3]	Crushed stone, 10-20 mm, kg / m3[3]	mixture, kg / m[3]
1-control	0.3-0.4	600	-	900	488	262	12
2-from MCU	0.3-0.4	510	80	900	488	262	10.2
3 - with Flask	0.3-0.4	570	30	900	488	262	11.4
4-with ICWL	0.3-0.4	540	55	900	488	262	10.8

2.7 stage. Testing the operational reliability of self-supporting concrete through a series of basic strength and durability tests.

2.7.1. Determination of frost resistance of concrete

The frost resistance test was performed using the second accelerated method according to [31] by freezing samples saturated with sodium chloride in air and then dissolving them in a sodium chloride solution. Accelerated tests for the second method are carried out according to the mode shown in Tables 17 and 18:

Table 17. Test conditions for determining frost resistance

Method and Grade of concrete frost resistance	Test conditions			Type of concrete
	Saturation environment	Freezing environment and temperature	Medium and defrost temperature	
Basic methods				
First F_1	Water	Air, minus (18±) ºS	Water (20±2)º	All types of concrete, except for road and airfield pavement concretes and structural concretes used under the influence of mineralized water
Second F_2	NaCl 5% water solution	Air, minus (18±)ºS	NaCl 5% aqueous solution, (20±2)ºS	Concretes of road and airfield surfaces and concrete structures operated under the influence of mineralized water
Accelerated methods				
Second	NaCl 5% water solution	Air, minus (18±)ºS	NaCl 5% aqueous solution, (20±2)ºS	All types of concrete, except road and airfield pavement concretes and structural concretes used under the influence of mineralized water, and concretes of light grades with an average density of less than D 1500
Third	NaCl 5% water solution	Air, minus (18±)ºS	NaCl 5% aqueous solution, (20±2)º S	All types of concrete, except light grades of medium density below D 1500

Table 18. Test mode

Model size, mm	Test mode			
	Freeze it		Thaw	
	Time, H, not less	Temperature, ºC	Time, H, not less	Temperature, ºC
100x100x100	2.5	minus (18±)ºS	2±0.5	20±2
150x150x150	3.5		3±0.5	

Data on the frost resistance of VET formulations with mineral additives are given in Table 19.

2.7.2. determination of concrete water absorption

Tests to determine the water absorption of concrete were carried out according to [32], when concrete samples are placed in a container filled with water, so that the water level in the container is approximately 50 mm higher than the upper level of the stacked samples.samples are placed on the inserts in such a way that the sample height is minimal (prisms and cylinders are placed on the side). The water temperature in the container should be (20 ± 2)°C. Samples are weighed with an error of not more than 0.1% on a conventional or hydrostatic balance by distilling water every 24 hours. When weighing on a conventional scale, samples removed from the water are pre-wiped with a wrung-out wet cloth. The mass of water flowing from the sample holes into the Scale must be added to the mass of the saturated sample. The test is still being conducted until the results of two weights in a row are no more than 0.1%.

Water absorption of concrete in each sample WM, wt%, is calculated using the formula with an error of up to 0.1%:

$$W_m = M_{in} – M_s / M_s * 100\%$$

$Mv_в$-Mass of the sample saturated with water, g, M_s-mass of the dry sample, g.

Data on water absorption of VET formulations with mineral additives are presented in Table 19.

2.7.3. Determination of the effect of mineral impurities on the shrinkage of self-compacting concrete)

Shrinkage deformations were determined on prismatic samples of the following dimensions 100*100*400 mm, taking into account the maximum size of the unit [33]. When determining shrinkage deformations, the batch should consist of a mixture of the control composition in accordance with the accepted algorithm and then at least 3 samples of prisms formed from each subsequent test composition. Then, after 24 hours of storage in a humid environment, the samples were removed from the molds and then tested. Based on the results of determining the relative value of shrinkage deformations of samples, the average value of relative shrinkage deformations for a series of samples is determined by the formula:

$$\bar{\varepsilon}(t) = \frac{\sum_{i-1}^{n} \varepsilon_1(t)}{n}$$

$\bar{\varepsilon}(t)$ - the average value of the relative shrinkage strain for each sample of this series.

n is the number of samples in the series.

Further, the average value of the relative shrinkage strain was converted to a percentage of the sample size.

Information on the precipitation of VET formulations with mineral is given in Table 19.

3. Results and discussions

At the next stage of the study, laboratory tests of the selected compositions were carried out to determine their physical, technical and operational properties, the summary results of which are shown in Table 19.

Table 19. Concrete performance properties

# composition	Frost resistance, cycles (F)	Volume water absorption, %	Shrinkage ,cscs,d
1-control	200	6.7	-0.25
2-from MCU	300	4.9	-0.17
3 - with Flask	250	6.5	-0.24
4-with ICWL	300	4.8	-0.18

Results of testing of concrete samples for frost resistance flask from F200 in concrete without impurities in pure cement

F250 shows a general tendency to increase the frost resistance index to F250 in samples of fused concrete and to F300 in samples of concrete with the addition of microsilicon MCU and metakaolin MK ZHL, the strength class of all samples is the same. It should also be noted that the volume water absorption rate decreased to 30% and the strain shrinkage value decreased to 0.07% in concrete samples with the addition of microsilicon MCU and metacaolin MCL, which allowed us to obtain research results with the appearance of additional crystallization centers and a decrease in the pore space in the concrete body by reactions of active pozzolanic mixtures (active SiO_2 microsilicon$_2$demonstrates coordination with theoretical assumptions about $Ca(OH)_2$ with an active mineral additive-binding of SiO_2 to a slightly soluble compound-calcium hydrosilicate: $Ca(OH)_2 + SiO_2 + mH_2O = CaO{*}SiO_2{*}nH_2O$ [27].

In addition, one of the most common problems on a construction site is the formation of shrinkage cracks. Since PTOis a special concrete with an increased volume composition of cement dough, it was necessary to show that the use of mineral additives containing PTO reduces the risk of shrinkage cracks [8]. According to the measured parameters of sedimentation deformations of self-supporting concrete using various types of mineral additives, it can be said that the use of mineral additives can reduce the sedimentation deformations of cement stone by increasing the CSH(B) crystallization centers and, accordingly, reducing the gel component of cement stone with a large amount of adsorbed H2o in the pores, which is the result of electron-microscopic analysis [36].

Figure 2. products made of secondary and ordinary cast concrete After facing

According to the results of production testing, sandy loam products with micro-silica MCU and METAKAOLIN MKL have a good surface (class A1) and strength characteristics are higher than those of PTO in a row of the same class. On the Figure 2 FBS products are presented after the release of 160.40.80.

Table 20. Strength of auxiliary compounds tested on VET products in production

# composition	Compressive strength of concrete and, MPa		
	3 days	7 days	28 days
1) ordinary cast concrete C30 / 35	21.2	29.8	35.4
SUB with MCU S30 / 35	27.9	34.7	38.1
SUB with ICWL C30 / 35	28.3	35.1	37.9

By replacing part of the cement with optimal values of deformation and viscosity with MKU and MKZL mineral admixtures, products 1 and 3 molded from the experimental compositions showed the quality of the A1 surface and the dynamics of the strength set by 20-25% higher than the concrete poured without admixture, as a result, we found that the concrete mixture, respectively we see that it is not compacted and partially stratified. low indicators of surface quality and durability, which is consistent with previously obtained results [8].

4. Conclusions

Based on the results of the tests, the following can be assumed:

- The mixture that replaces part of the cement with opal-chalcedony opac has the greatest water demand and the least homogenous structure, in which both calcium hydrosilicates, hydroaluminates and hydroferrites are observed, which is evident in the DTA images and data, the homogeneity of this structure shows the lowest values of 3 whereas, during further tests for reliability of use, mineral impurities have a negative effect on frost resistance and water absorption tests, as well as on the strength characteristics of the final conglomerate;

- The use of MKU microsilica and metakaolin μl in the composition of concrete increases important operational characteristics, such as frost resistance, by 100 cycles, reduces bulk water absorption of concrete by 30-35% and shrinkage deformations by 0.07%. Apparently, when mineral fillers are introduced into the mixture, a significant additional surface of the section appears: "additional - water".

- According to the data of production tests, microsilica MKU and metakaolin MKU can be recommended for use in production. However, since a small amount of hyperplasticizer is required to obtain the required rheological parameters of the self-sealing mixture when using MKU microsilica, it is more effective to use MKU microsilica in production.

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Темірбетон бұйымдарын өндіруде өздігінен тығыздалатын бетондардың пайдалану қасиеттеріне минералды қоспалардың әсері

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Аңдатпа. Құрылыс саласында ресурс үнемдейтін технологияларды енгізу міндеттерін шешу тұрғысынан өзін-өзі қамтамасыз ететін бетон қоспаларының құрамдарының тиімділігі мәселесі жетекші орындардың бірін алады. Мақалада практикалық қолдану тұрғысынан бетонның осы түрінің реологиялық сипаттамаларын, экологиялық таза және үнемділігін жақсарту жолдарының бірі ретінде жалпы минералды толтырғыштардың өзін-өзі қамтамасыз ететін бетон қоспаларына енгізудің әсері қарастырылады. Мақалада жақсы зерттелген микрокремний mcu және метакаолин mcl-ден опало-халцедон опокасына дейін минералды қоспалардың 3 түрі қарастырылған, олар өзін-өзі қамтамасыз ететін бетондарда сыналмаған. Сынақ нәтижелері цементтің бір бөлігін минералды қоспамен ауыстырған кезде бетон қоспасының реологиялық көрсеткіштерін жүйенің тұтқырлығы мен пайдалану сипаттамалары бойынша оңтайлы мәндерге дейін жақсартты, сондай-ақ Fup бетонының аязға төзімділігін F 300-ге дейін арттырды, бетонның көлемді су сіңіруін 30%-ға дейін төмендетті, бетонның осы түрінде минералды қоспаны қолданған кезде шөгу деформацияларын азайтты-0.07 және төмендету мүмкіндігін растады. Пайдаланудың қарапайымдылығы үшін сынақ нәтижелері көрнекі Графиктер мен кестелер түрінде ұсынылған.

Негізгі сөздер: *аязға төзімділік, суды сіңіру, шөгілетін деформациялар, минералды қоспалар, цемент, өзін-өзі қамтамасыз ететін бетон.*

Влияние минеральных добавок на эксплуатационные свойства самоуплотняющихся бетонов при производстве железобетонных изделий

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Аннотация. С точки зрения решения задач внедрения ресурсосберегающих технологий в строительной отрасли вопрос эффективности составов самонесущих бетонных смесей занимает одно из ведущих мест. В статье рассматривается влияние введения в самонесущие бетонные смеси общеупотребительных минеральных наполнителей как одного из путей улучшения реологических характеристик, экологичности и экономичности данного вида бетона с точки зрения практического применения. В статье рассмотрены 3 вида минеральных добавок, от хорошо изученных mcu микрокремния и mcl метакаолина до опоки опало-халцедона, которые не были испытаны в составе самонесущих бетонов. Результаты испытаний улучшили реологические показатели бетонной смеси при замене части цемента минеральной добавкой до оптимальных значений по вязкости и эксплуатационным характеристикам системы, а также повысили морозостойкость бетона Fup до F 300, снизили объемное водопоглощение бетона до 30%, уменьшили усадочные деформации при использовании в данном виде бетона минеральной добавки -0.07 и подтвердили возможность понижения. Для удобства использования результаты испытаний представлены в виде наглядных графиков и таблиц.

Ключевые слова: *морозостойкость, водопоглощение, термоусадочные деформации, минеральные добавки, цемент, самонесущий бетон*.

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