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COMPREHENSIVELY MODIFIED CONCRETES BASED ON NATURAL AND TECHNOGENIC MINERAL MICROFILLERS

***Abstract**: The article presents the results of a study on the influence of natural and technogenic mineral microfine fillers in combination with superplasticizer SP-1 on the rheological, physical-mechanical, and performance properties of highly flowable and resource-efficient concretes. The optimal parameters for modifying cement binder with an increased water-cement ratio have been established, the features of hydration and structure formation of filled cement compositions have been determined, and the possibility of obtaining highly flowable concretes with reduced cement consumption of up to 70% without compromising strength characteristics has been demonstrated. Based on comprehensive research, technological recommendations have been proposed, and the effectiveness of using microfine fillers in the industrial production of concrete and reinforced concrete products has been confirmed.*

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Introduction

The current trends in the development of the construction industry require the introduction of energy- and resource-saving technologies, including in the production of concrete and reinforced concrete structures. The increase in the share of monolithic construction, the use of highly reinforced and thin-walled prefabricated elements, necessitates a growing demand for super-movable concretes with high technological efficiency, structural stability, and improved operational characteristics.

One of the most promising areas is the comprehensive modification of cement systems through the combination of mineral microtol fillers and superplasticizers. Natural (ground quartz sand) and technogenic (TPP ash) mineral additives allow for the regulation of the dispersity, surface activity, and structure formation of cement stone, ensuring the formation of a dense, homogeneous, and less defective matrix.

Despite a significant number of studies, the issues of the mutual influence of dispersity, the nature of microtol fillers, and their interaction with the superplasticizer at an increased water-cement ratio have not been sufficiently studied. The development of economical compositions of highly mobile concretes with minimal cement consumption while preserving strength and operational properties is also relevant.

Experimental research

During the experimental studies, Portland cement of the CEM 0 32.5 H brand, produced by OJSC “Ahangarancement” (GOST 31108-2020), was used as a binder. The chemical and mineral compositions of Portland cement clinker from OJSC

“Ahangarancement” are as follows, wt.%: SiO_2 - 21.66; CaO - 64.95; Al_2O_3 - 5.01; Fe_2O_3 - 4.01; MgO - 3.42; SO_3 - 0.40; R_2O - 0.46; C_2S - 16.33; C_3S - 60.22; C_3A - 6.48 and C_4AF - 12.19. According to their physical and mechanical indicators (Table 1 and 2) Portland cement accepted for research meets the standard requirements.

Table 1. Physical properties of Portland cement

Type of cement	Average density g/cm^3	True density g/cm^3	Fineness of grinding		Normal density %
			Specific surface area cm²/g	Residue on sieve 0.08%	
Portland cement Ahangarancemen brand CEM 0 32.5H	1,21	3,2	3000	8,5	26,0

Table 2. Physical and mechanical properties of Portland cement

Type of cement	Setting times hour–min		Ultimate strength after 28 days of hardening, MPa		Uniformity of change in volume
	beginning	end	bend	compression	
Portland cement Ahangarancemen brand CEM 0 32.5H	1–10	6–20	5,80	41,80	endured

The river quartz sand of the Qoyliq quarry, with a particle size modulus of Mkr=1.81 and an average density of 2000 kg/m^3, was used as a fine aggregate for the concrete (GOST 8736-2014). The content of foreign particles (clay, dust, and silt) did not exceed 0.15%. The sand used fully met the standard requirements. As a coarse aggregate, Eyvalek quarry gravel was used, with fractions of 5-10 and 10-20 mm, and an average density of 1400 kg/m^3 (GOST 8267-93). The content of clay, silt, and dust impurities did not exceed 0.4%.

The following were used as mineral aggregates for concrete: May quarry's crushed quartz sand, Angren TPP ash, and crushed limestone.

To conduct research, the quartz sand of the May quarry and the limestone were ground in a SHLM-100 laboratory ball mill to a specific surface area of 100 ± 10 kg/m^3 and 200 ± 10 kg/m^3, respectively. The selection of the dispersity of quartz sand and limestone was based on the results of previously conducted research [123, 165]. The limestone had the following average composition: CaO - 54.79%, SiO_2 - 1.0%, Fe_2O_3 - 0.61%, SO_3 - 0.08%.

The ash-discharge from the electrostatic precipitators, formed during the combustion of Angren basin coals at the thermal power plant, had a specific surface area of 420 ± 10 kg/m^3 and met the requirements of GOST 3470-542-81 *Thermal Power Plant ash-discharge. General Technical Requirements. The chemical composition of the waste ash is presented in Table 3 (according to the data of the TPP Laboratory No. 22).

Table 3. Chemical composition of fly ash of the Angren Thermal Power Plant

Chemical composition, wt.%									Loss on ignition
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	TiO_2	K_2O_3+ Na_2O_3	R_2O	
49,7	19,1	10,5	11,5	3,6	1,4	0,2	2,8	1.67	1,2

In accordance with GOST 25818–83 “Fly ash from thermal power plants for concrete. Technical conditions,” the ash used is brown coal, basic, type P, class A. The residue on sieve No. 008 (aperture size 0.08 mm) is no more than 15% by mass. The basicity modulus, expressed as the ratio $(CaO+MgO)/(SiO_2+Al_2O_3)$, is 0.21.

Fly ash carried out of the fuel combustion zone by flue gases was captured by electrostatic precipitators and then deposited in cyclones. High dispersibility indicates a predominance of fine and ultrafine ash fractions, which, as a rule, contain the largest amount of spherical particles and less unburned organic residues.

The chemical additive used for concrete was the superplasticizer "Polyplast SP-1" (TU 5870-005-58042865-2005) manufactured by the POLYPLAST Group of Companies (Russia). The superplasticizer "Polyplast SP-1" is a new generation chemical additive based on naphthalene sulfonic acid and formaldehyde. The additive allows obtaining high-quality concrete mixtures with a slight acceleration of strength gain and stability of working characteristics over a long period of time without any effect on the setting delay. The technical characteristics of the superplasticizer "Polyplast SP-1" are given in Table 4.

Table 4. Technical characteristics of the superplasticizer "Polyplast SP–1"

Name of indicator	Meaning
Raw material base	naphthalene sulfonic acid
Color and delivery form	Powder or liquid, brown in color
Solution density (at 20°C)	1.17 ± 0.01 g/cm^3
ρH	7,4 ±1,0
Chloride content	< 0.1% by weight
Alkali content	< 3.0% by weight (as Na_2O equivalent)
Hazard class	Class 3 (Moderately hazardous)
Standard	TU 5870–005–58042865–2005 with amendments No. 1 and 2.

The studies included:

▪ determination of rheological parameters of cement compositions;

• strength testing in accordance with GOST 10180;

• analysis of hydration kinetics using the DTT method (Thermoscan–2);

• determination of frost resistance in accordance with GOST 10060–2012;

The experimental data were processed using mathematical experiment planning and regression modeling methods. Three factors were considered: water-cement ratio (X_1), degree of filling (X_2), and specific surface area of the filler (X_3).

Research results

1. Rheological properties and strength of filled cement compositions.

It has been established that the introduction of mineral microfillers in an amount of 5–10% causes an increase in the strength of cement stone by 5–15% (at W/C ≥ 0.75). Analysis of the dependence $Rb = f(Cv)$ revealed the presence of two extremes of strength, which indicates a complex mechanism of structure formation at low filler dosages.

With an increase in W/C, a shift of the optimal degree of filling to the region of large values is observed, which is associated with the strengthening of interphase interactions and the role of bound water.

The response functions selected were the compressive strength of filled cement compositions after 28 days of hardening under normal conditions and the mobility of the binder, which were investigated in a three-factor experiment as regression functions:

$$U_1 = f(X_1, X_2, X_3) \quad (1)$$

where X_1 is the water-cement ratio, X_2 is the degree of binder filling, and X_3 is the specific surface area of the mineral filler.

At a significance level of α = 0.05, the following adequate models were obtained:

a) for compressive strength (MPa):

$$X_1 = 17{,}9 - 10{,}35X_1 + 2{,}78X_2 + 0{,}3\,X_3 + 2{,}03X^2{}_1 + 0{,}58X^2{}_2 + 1{,}63X^2{}_3 + 0{,}4X_1 \bullet X_2 - 2{,}35X_1 \bullet X_3 + 0{,}75X_2 \bullet X_3 \quad (2)$$

b) for mobility (mm):

$$X_2 = 96{,}0 + 13{,}63\,X_1 - 17{,}25X_2 - 13{,}38X_3 - 2{,}13X^2 - 5{,}38X^2{}_2 +- 1{,}38X^2{}_3 + 0{,}5X_1\,X_2 + 0{,}75X_1 * X_3 - 1{,}0X_2 * X_3 \quad (3)$$

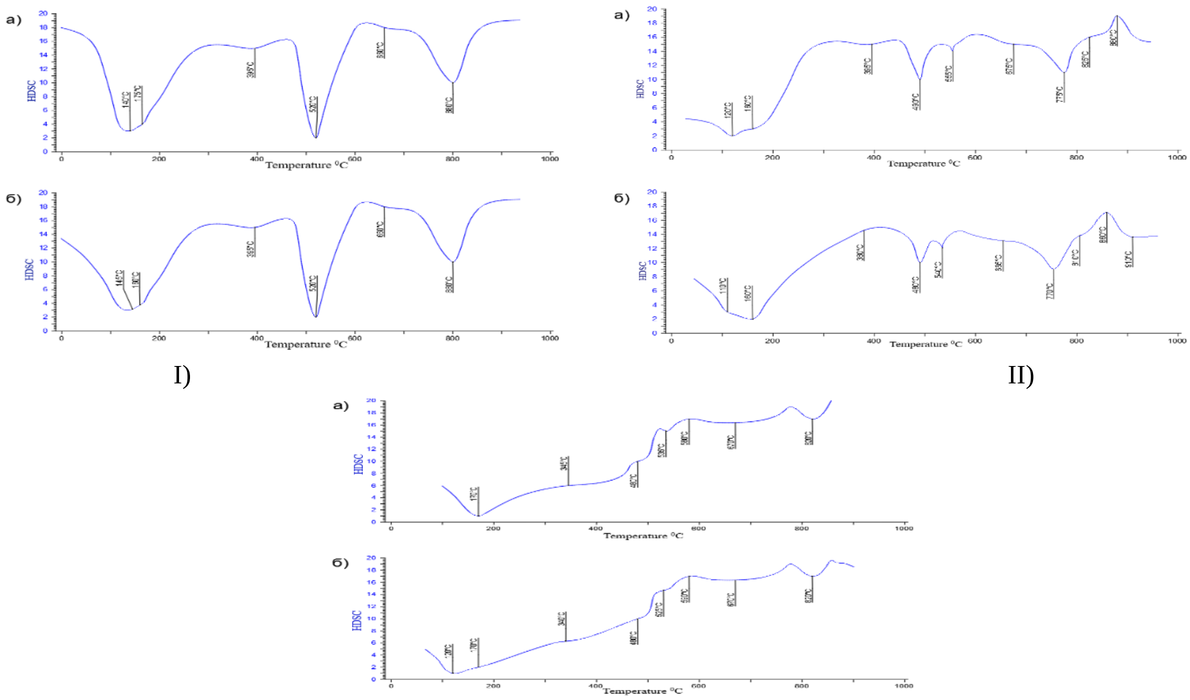
Table 5. Experiment planning conditions

Name of factors	Designation	Variable values at the level of variation		
		–1	0	+1
Water-cement ratio, W/C	X_1	0,6	0,75	0,90
Filling level, H/C+H, %	X_2	50	60	70
Specific surface area of filler, kg/m^3	X_3	100	200	300

2. Hydration and structure formation

Differential thermal analysis (DTA) was used to study the degree of hydration and phase composition of new phases formed in filled cementitious binder in the presence of large amounts of water. The first sample was crushed cement stone without filler (reference 1), while the second sample had the same composition and was prepared only in a high-speed mixer (reference 2). The third sample was cement stone optimally filled with crushed quartz sand, and the fourth sample was a variant with the addition of SP-1 superplasticizer in an amount of 0.8% of the mass of the solid part of the binder.

The DTA results are presented as DTA curves in Fig. 1.



I) II) III)

Fig. 1. DTA curves of pure and optimally filled cement stone
I) pure cement stone; II) cement stone filled with quartz sand;
III) cement stone filled with ash–slag from a thermal power plant; a) without SP; b) with SP

The results of DTT and PCA revealed that:

❖ filler minerals do not alter the overall cement hydration mechanism;

❖ changes in phase composition are observed: formation of additional C–S–H structures, complication of polymorphic transformations of portlandite;

❖ when fly ash is used, the formation of hydromagnesite and SH(B) modifications is observed.

This confirms the catalytic role of filler microtones in the structure formation processes of cement stone.

3. Strength of concrete and strength gain kinetics

Initially, the kinetics of strength growth of concretes made on the basis of filled cement binders were studied. Ground quartz sand with $S_{relative}$ = 100 kg/m^3 and ash from thermal power plants with $S_{relative}$ = 420 kg/m^3 were used as mineral microfillers. The slump of the concrete mix was 12–14 cm. Superplasticizer SP-1 was added to the water. Concrete samples were prepared using traditional technology. Cubic and prismatic samples were hardened under normal conditions in a special chamber. The composition of the concrete mixes and the test results are shown in Table 6.

Table 6. Kinetics of concrete compressive strength growth

Concrete composition and cement consumption per 1m^3	Filling level, %	Type and amount of additive, %	Compressive strength limit, MPa at age			
			3 days	7 days	28 days	90 days
Filler: ground quartz sand with $S_{relative}$= 100 kg/m^3 C= 220 kg						
1:2,0:6,65:0,90	–	–	4,2	7,9	12,8	17,3
0,3:2,3:6,9:0,80	70	0,8% SP–1	5,0	9,0	12,6	17,8
C=250 kg						
1:1,8:5,61:0,84	–	–	5,1	9,3	15,4	20,0

0,3:1,9:5,7:0,75	60	0,8% SP–1	6,1	10,9	14,9	22,1
0,4:2,0:6,6:0,77	50	0,8% SP–1	6,0	10,4	14,3	21,9
Filler: ash – fly ash from thermal power plant with $S_{relative}$ = 420 kg/m^3 C=220 kg						
1:2,0:6,65:0,90	–	–	4,2	7,9	12,8	17,3
0,3:2,3:6,9:0,84	70	0,8% SP–1	5,3	9,4	13,0	19,9
C=250 kg						
1:1,8:5,61:0,84	–	–	5,1	9,3	15,4	20,0
0,4:1,9:5,7:0,77	60	0,8% SP–1	6,9	11,5	15,6	23,2
0,5:2,0:6,6:0,75	50	0,8% SP–1	6,5	10,1	14,1	22,1

Optimal concrete compositions with 50–70% cement replacement with mineral fillers and 0.8% SP–1 provided:

- a 20–35% increase in early strength,
- achievement of 28-day strength comparable to the control (12–16 MPa at a cement consumption of 150–175 kg/m³),
- increased structural density and matrix homogeneity.

4. Water separation and frost resistance

The frost resistance of concrete was assessed based on its compressive strength after freezing at a temperature of –20°C and thawing in water in accordance with GOST 10060–2012 "Concrete. Methods for determining frost resistance." For proposed structures of buildings and structures of class II and III in terms of responsibility according to the requirements of KMK 2.03.01–96 "Concrete and reinforced concrete structures," heavy concrete must comply with frost resistance grades F35, F50, and F75. The compositions and physical and mechanical properties of filled concrete made from mixtures with increased water content, tested for frost resistance, are given in Table 7.

Table 7. Compositions and properties of filled concrete

Type of filler	Composition No.	Material consumption per 1 m3 of concrete, kg: Cement	Filler	Sand	Crushed stone	Water	Amount of SP–1, % of solid mass.	Compressive strength, MPa at 28 days
Ground quartz sand	1	45	175	506	1438	175	0,8	12,6
	2	75	175	480	1428	180	0,8	14,9
	3	100	150	500	1425	182	0,8	14,3
Fly ash	4	45	175	506	1383	180	0,8	13,0
	5	100	150	480	1408	183	0,8	15,6
	6	125	125	500	1390	186	0,8	14,1

It has been established that:

• Water separation in filled mixtures is reduced by 2–3 times.

• SP–1 further reduces water separation by 1.5 times.

• The frost resistance of the compositions corresponds to F35–F75, which meets the requirements of KMK 2.03.01–96.

Conclusions

The studies conducted confirmed the high efficiency of complex modification of cement systems with natural and man-made mineral micro-fillers in combination with SP-1 superplasticiser. It was established that:

1. Mineral micro-fillers contribute to the formation of a dense and less defective structure of cement stone.

2. At elevated W/C ratios, it is possible to obtain highly mobile concrete mixtures with low water separation and a stable structure.

3. Replacing 50–70% of the cement with mineral fillers results in concrete with strength comparable to that of the control compositions.

4. Modified concretes have increased frost resistance, reduced shrinkage and improved structural stability.

The results obtained are of scientific and practical importance for the development of resource-saving technologies in the production of highly mobile and environmentally friendly concretes.

References:

1. Adylhodzhaeva, A.I., Mahamataliev, I.M., Turgunbaev, U.Zh., & Coj, V.M.; pod.obshh. red. Adylhodzhaeva A.I. (2016). *Intensivnye tehnologii stroitel`stva.* (Monografija), (228p.). Tashkent, Izd- vo «Fan va tehnologija».
2. Adylhodzhaev, A.I., Mahamataliev, I.M., & Coj, V.M.; Pod. obshh. red. Adylhodzhaeva A.I. (2018). *Kompozicionnye stroitel`nye materialy* (Monografija), LAMBERT» ACADEMICPUBLISHING, 2018 -176 p.
3. Adylhodzhaev, A.I., Mahamataliev, I.M., Coj, V.M., & Kesarijskij, A.G. (2018). *Metodologicheskie osnovy issledovanija mnogokomponentnyh vysokokachestvennyh betonov novogo pokolenija* (Monografija), «Fan va tehnologija», 196 p.
4. Adylhodzhaev, A.I., Mahamataliev, I.M., Coj, V.M., & Umarov, K.S. (2020). *Kompleksno-modificirovannye betony s organomineral`nymi dobavkami* (Monografija), «Innovacion rivozhlanish nashrijot-manbaa uji», 235 p.
5. Adylhodzhaev, A.I., Mahamataliev, I.M., & Coj, V.M. (2018). *Reshenie optimizacionnyh zadach v tehnologii betona metodom matematicheskogo planirovanija jeksperimentov.* Metodicheskoe posobie po discipline “Innovacionnye tehnologii stroitel`nyh materialov”, TashIIT, 80 p.
6. Bazhenov, Jy.M. (2011). *Tehnologija betona.* — Moscow: ASV.
7. (2012). *GOST 10180-2012. Betony. Metody opredelenija prochnosti.*
8. (2012). *GOST 10060-2012. Betony. Metody opredelenija morozostojkosti.*
9. (n.d.). *GOST 24544-81. Betony. Metody opredelenija usadki.*
10. Kasimov, E.U., et al. (2020). *Modern trends in composite concrete technology*. Tashkent.