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STRUCTURAL CHARACTERISTICS AND PERFORMANCE OF CONCRETE WITH A COMPOSITE MODIFYING ADDITIVE

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Abstract

Introduction: The paper addresses the effect of a composite modifying mineral additive based on waste — tailings from the Balkhash Mining and Processing Plant — and microsilica on the structural characteristics and performance of heavy concrete. **Purpose of the study:** We aimed to select optimal B25 and B35 concrete mixes based on the MV-D20 modified binder with the composite additive in its composition and evaluate the characteristics of concrete. **Methods:** In the course of the study, standard methods were used to design concrete mixes and test the characteristics of concrete. Proportioning was performed in accordance with State Standard GOST 27006-86 “Concretes. Rules for Mix Proportioning”. The physical and mechanical properties of heavy concrete were determined in accordance with State Standard GOST 10180-2012 “Concretes. Methods for Strength Determination Using Reference Specimens”. The strength of concrete was assessed in accordance with State Standard GOST 18105-2018 “Concretes. Rules for Control and Assessment of Strength”. **Results:** It was established that in terms of the rate of strength gain, the designed heavy concrete mixes are fast-curing. In the initial curing period of 7 days, B25 and B35 concretes gain 90.1 and 85.4% of the required standard strength, respectively. The average values of water absorption in B25 and B35 concretes are 4.20 and 3.46%, respectively. In terms of water tightness, concrete mixes have W10 and W12 grades. The application of the MV-D20 modified binder with the composite additive consisting of tailings and microsilica instead of standard sulfate-resistant Portland cement will reduce the relative deformation of B35 concrete in an aggressive environment by 12%.

Keywords

Composite mineral additive, sulfate-resistant Portland cement, tailings, microsilica, strength, fast-curing concrete, water absorption, water tightness.

Introduction

Modern building materials science offers a lot of theoretical insights and case studies on the use of finely-dispersed active mineral additives. Their application in the production of concrete and reinforced concrete makes it possible (Guvalov et al., 2017; Lothenbach and Winnefeld, 2006; Ngo et al., 2020a; Slavcheva et al., 2020; Zvezdov and Mikhailov, 2001):

- to reduce concrete mix disintegration in transportation and improve its workability;
- to improve the structural characteristics and performance of heavy concrete;
- to increase compression strength;
- to increase significantly the durability of concrete and reinforced-concrete structures.

However, the use of waste from mining and processing plants in the Republic of Kazakhstan as mineral additives to cement binders has not been sufficiently studied.

Studies (Zhilkibaeva and Estemesova, 2020; Zhilkibayeva, 2021) show that the activation of waste — tailings from the Balkhash Mining and Processing Plant — with microsilica increases significantly the chemical activity of the additive to cement and, thus, determines the strength characteristics of concrete.

Previously, the following optimal composite mineral additive was chosen: 60% tailings from the Balkhash Mining and Processing Plant + 40% microsilica. It was established that with a microsilica content higher than 40%, the water demand of the mix increases. The pozzolanic activity of the composite additive consisting of 60% tailings from the Balkhash Mining and Processing Plant + 40% microsilica is 48 mg/g. Thus, when microsilica is introduced into tailings, the pozzolanic activity of the composite additive doubles (Zhakipbekov et al., 2021a, 2021b; Zhilkibaeva and Estemesova, 2020; Zhilkibayeva, 2021).

Microsilica is a critical component in the production of high-performance concrete. It has a unique ability to positively affect the properties of concrete, improving its qualitative characteristics: reducing water absorption and increasing strength, frost resistance, chemical resistance, sulfate resistance, wear resistance, etc. (Kaprielov et al., 1992).

Microsilica also affects the structure of concrete at the nanoscale and, according to available data, increases its compression strength (Batrakov et al., 1989). An increase in strength is attributable to pore filling with small microsilica particles and the formation of additional C-S-H bonds during the pozzolanic reaction of microsilica and $Ca(OH)_2$ (Zhang et al., 2016). Besides, microsilica reduces the shrinkage and water permeability of concrete and increases its wear resistance and grip on steel (Nesvetayev, 2006).

Those scientific principles and practical recommendations on the maximum cement content and its rational reduction that were set forth in some papers and monographs cannot be applied to the technology of high-strength concrete curing under normal conditions since there are other problems that need to be solved (Lothenbach et al., 2008; Singh et al., 2017; Yestemessova et al., 2020; Zhakipbekov et al., 2021a, 2021b; Zhilkibayeva et al., 2021):

- ensuring fast strength gain in the initial curing periods and high required strength of concrete;
- choosing aggregates having good compatibility with superplasticizers to ensure maximum rheological effect;
- obtaining higher dispersion in the aggregate (as compared to that in cement) to ensure high reactivity with cement hydration products and the formation of additional crystallization centers;
- ensuring low porosity and high density of concrete.

Materials and Methods

To make heavy concrete, a modified binder was used based on sulfate-resistant Portland cement CEM I 42.5N SS (ordinary curing) by CaspiCement LLP (Mangystau Region) with a composite additive. In terms of its physical and mechanical properties as well as mineral and chemical composition, sulfate-resistant Portland cement meets the requirements of GOST 22266-2013 “Sulfate-Resistant Cements. Specifications”.

Tailings from the Balkhash Mining and Processing Plant of the following composition were used as a composite mineral additive to the binder based on sulfate-resistant Portland cement in the amount of 12% of the cement mass:

Tailings from the Balkhash Mining and Processing Plant	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	Na_2O	S_{tot}
	74.40	1.25	0.25	1.97	1.10	-	10.36

To activate waste (tailings from the Balkhash Mining and Processing Plant), microsilica in the amount of 8% of the cement mass was used. Thus, an MV-D20 modified binder with a composite additive was obtained (Zhakipbekov et al., 2020).

Sand from the Beineu deposit (Mangystau Region) and crushed stone of 5–10 and 10–20 mm size by Koktas-Aktobe JSC were used as fine and coarse aggregates.

In terms of its grain composition, strength (crushability), the content of lamellar (flaky) and needle-shaped grains, and the content of dust-like and clay particles, crushed stone of 5–10 and 10–20 mm size by Koktas-Aktobe JSC meets the requirements of State Standard GOST 8267-93 “Crushed Stone and Gravel of Solid Rocks for Construction Works. Specifications”. The fineness modulus of sand from the Beineu deposit is 2.75 and sand is classified as coarse, grade I. Sand from the Beineu deposit meets the requirements of State Standard GOST 8736-2014 “Sand for Construction Works. Specifications”.

To ensure targeted control over the rheological behavior of cement systems so as to obtain concrete with specified structural characteristics and performance, such functional additives as MasterAir 200 (air-entraining admixture) and MasterGlenium 305 superplasticizer were used in the amounts as per the manufacturers’ recommendations.

Proportioning was performed in accordance with State Standard GOST 27006-86 “Concretes. Rules for Mix Proportioning”.

The physical and mechanical properties of heavy concrete were determined in accordance with:

• State Standard GOST 10180-2012 “Concretes. Methods for Strength Determination Using Reference Specimens”;

• State Standard GOST 18105-2018 “Concretes. Rules for Control and Assessment of Strength”.

The compression strength of test specimens was determined with the use of a C23CO2 CONTROLS automatic compression tester.

An accelerated procedure to determine the water tightness of B35 concrete with the modifying additive by its air permeability was carried out in accordance with State Standard GOST 12730.5-84 “Concretes. Methods for Determination of Water Tightness”. For that purpose, an Agama-2RM device was used.

Water absorption tests were performed to determine concrete resistance to the penetration of aggressive salts according to paragraph 5.5, item 41, CIV-CU-850-TCO specification. The test procedure was as follows:

- cores with a diameter of 100 mm and a length of 150 mm were cut out of 10 test specimens (test cubes) with a portable SOLGA SDR 450 diamond drill rig;
- the core samples were weighed to determine their wet mass;
- to determine the moisture-free mass, the core samples were placed in a drying oven. They were continuously dried at a temperature of 105°C for 72 hours;
- the samples were cooled in the drying oven for 24 hours and weighed to determine the moisture-free mass;
- the samples were saturated with water for 30 minutes;
- the surface of the samples was dried, and the samples were weighed to determine the mass of absorbed water.

Differential thermal analysis was carried out with a Q-1500D derivatograph in the temperature range of 25–1500°C in the air flow. The rate of temperature increase was 7.5°/min. Based on the results of thermal transformation and differential mass loss, the amount of $Ca(OH)_2$ was determined.

Sulfate resistance was determined in accordance with State Standard GOST R 56687-2015 "Protection of Concrete and Reinforced-Concrete Constructions from Corrosion. Test Method of Sulfate Resistance of Concrete". The standard takes into account the main regulations of ASTM C 452-06 "Standard Test Method for Potential Expansion of Portland-Cement Mortars Exposed to Sulfate".

Results and Discussion

When the strength properties of B35 concrete with the composite additive with MasterGlenium 305 superplasticizer were determined, it was established that at a constant W/C ratio, in the first 24 hours, the rate of strength gain slows down a bit as compared to concrete based on a non-modified binder. By day 3, the rate of retardation is reduced. After seven days of curing, an increase in the rate of strength gain can be observed. The physical and mechanical properties of B25 and B35 heavy concretes based on the MV-D20 modified binder are given in Table 1.

Table 1. Physical and mechanical properties of B25 and B35 heavy concretes based on the MV-D20 modified binder with the composite additive

Concrete grade	Concrete density, kg/m³	Porosity, %	Compression strength, MPa (at a particular age of curing, days)			
			7	28	90	360
B25	2360	4.5	25.0	31.0	32.0	32.5
B35	2440	4.4	32.0	43.0	43.5	44.0

When the strength of B35 heavy concrete with the composite modifying additive was assessed in accordance with State Standard GOST 18105-2018 "Concretes. Rules for Control and Assessment of Strength", it was established that the average strength of the designed concrete composition is 40.75 MPa. The standard deviation of strength in a batch is 1.35 MPa, and the current coefficient of strength variation in a batch is 3.5%. The required strength of B35 concrete with the composite modifying additive is 37.45 MPa, and the required strength of B25 concrete is 27.75 MPa.

Among the important indicators that determine the quality of binders, the following can be mentioned: activity and the kinetics of strength gain with an increase in the curing period or when using concrete and reinforced-concrete products.

Fig. 1. presents the kinetics of strength gain in B25 and B35 heavy concretes based on the MV-D20 modified binder with the composite additive. It shows that after one day of curing, B25 and B35 concretes gain 56.7 and 55.3% of the required strength, respectively.

The designed B25 and B35 concrete mixes based on the MV-D20 modified binder with the composite additive gain the required standard strength after 28 days of curing. In the initial curing period of 7 days, they gain 90.1 and 85.4% of the required standard strength, respectively.

Based on the obtained results, it is possible to divide the mechanism of hydration and curing (with regard to heavy concrete based on the MV-D20 modified binder with the composite additive) into the following two stages:

- the stage of intense hydration (4.5 hours of concrete mix preparation – 7 days of curing). At this stage, clinker minerals are hydrated, the pozzolanic activation of the mineral additive takes place, and stable hydrates are formed;

- the stage of slow hydration (7 days – one year). At this stage, pozzolanic reactions prevail.

Thus, in terms of the rate of strength gain, the designed mixes of heavy concretes based on the MV-D20 modified binder with the composite additive consisting of tailings and microsilica are fast-curing.

To determine if it is possible to use B35 heavy concrete with the composite additive for the construction of facilities to be operated in moderately and highly aggressive environments, water absorption, water tightness, and sulfate resistance

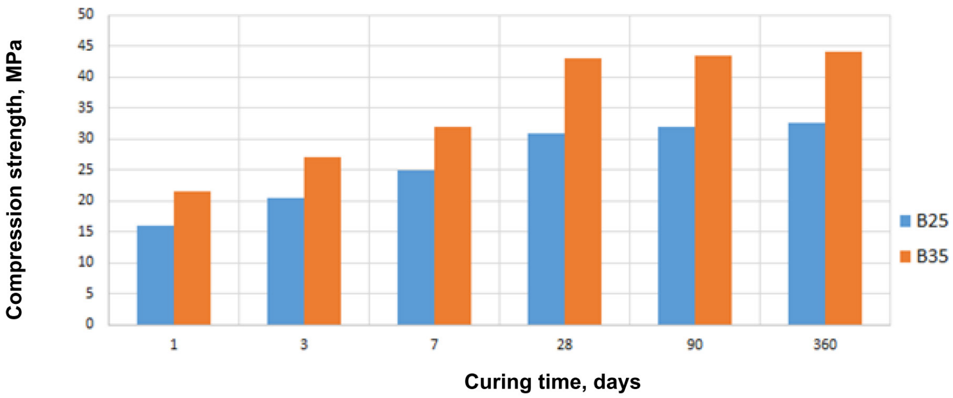

Fig. 1. Kinetics of strength gain in heavy concrete based on the MV-D20 modified binder with the composite additive

were also studied.

The high specific surface area (up to 1500 m^2/kg) in combination with the amorphized structure of microsilica particles and silicon carbide elements ensure high reactivity (Batrakov et al., 1989; Zhang et al., 2016).

Table 2 presents data on the effect of the composite additive consisting of 60% tailings + 40% microsilica on the amount of formed $Ca(OH)_2$ in C_3S stone.

Table 2. Effect of the composite mineral additive on the amount of $Ca(OH)_2$ in C_3S stone

Additive, %	Amount of Ca(OH)2, % (at a particular age of curing, days)				
	3	7	28	180	360
Without additive	12.0	14.0	20.5	22.5	24.5
60% tailings from the Balkhash Mining and Processing Plant + 40% microsilica	11.5	12.0	14.5	15.0	15.5

The experimental data (Table 2) show that after 28 days of curing, the composite mineral additive reduces the amount of Portlandite by 6.0%. With an increase in the curing period with regard to C3S stone with the composite modifying additive up to 360 days, the $Ca(OH)_2$ content is reduced by 9.0%.

In their paper, Tang et al. (2017) showed that when introduced into the composition of a modifying additive, due to their high pozzolanic activity, microsilica and fly ash from the Vung Ang thermal power plant reduce the amount of Portlandite in cement stone at the age of 28 days of normal curing by 1.27–3.29% as compared to the reference composition, which does not contradict our data.

There is an opinion (Bazhenov, 2002; Lothenbach et al., 2008; Singh et al., 2017; Tang et al., 2017; Yestemessova et al., 2020; Zhakipbekov et al., 2021a, 2021b; Zhilkibayeva et al., 2021) that a decrease in the amount of $Ca(OH)_2$ in cement stone increases the corrosion resistance of concrete in aggressive environments.

Table 3. Results of water absorption tests for B25 and B35 heavy concretes based on the MV-D20 modified binder with the composite additive

Core sample No.	Mass of the sample, g			Mass of water absorbed	
	before drying	after drying	after saturation with water for 30 minutes	g	%
Heavy concrete (B25)					
1	2560	2430	2490	60	4.44
2	2550	2440	2490	50	3.69
3	2540	2420	2480	60	4.46
Average value					4.20
Heavy concrete (B35)					
1	2520	2410	2450	40	2.99
2	2520	2430	2480	50	3.70
3	2520	2430	2480	50	3.70
Average value					3.46

a

b

c

d

Fig. 2. Testing of the core samples to determine water absorption in B25 and B35 concretes:
a — a portable SOLGA SDR 450 diamond drill rig; b — marking of the core samples; c — drying of the samples to determine the moisture-free mass (in a SNOL 58/350 laboratory low-temperature electric drying oven); g — weighing of the core samples after drying to determine the moisture-free mass (MWP-3000H laboratory balance, verification certificate No. VG-000000401 dated May 02, 2019)

Table 3 presents the results of water absorption tests for B25 and B35 heavy concretes based on the MV-D20 modified binder with the composite additive (Fig. 2).

Since the core samples had a length different from 75 mm, an adjustment coefficient was used to standardize the volume of the samples according to the requirements of State Standards GOST 12730.0 – GOST 12730.4-78 and GOST 12730.5-84. The adjustment coefficient K_a is 1.8.

The results of water absorption tests (Table 2) showed that water absorption in B25 concrete based on the MV-D20 modified binder with the composite additive consisting of tailings and microsilica is in the range of 3.69–4.46%. The average value of water absorption in B25 concrete is 4.20%. Water absorption in B35 heavy concrete is 2.99–3.70%. The average value of water absorption in B35 concrete is 3.46%.

The results of water tightness tests (Table 4) showed that the actual value of B25 concrete resistance to air penetration is in the range of 18.4–19.0 s/cm^3. In terms of water tightness, the B25 concrete grade is W10. As for B35 concrete with the composite additive, in terms of water tightness, it has grade W12. The actual value of its resistance to air penetration is in the range of 24.4–26.6 s/cm^3.

Studies of sulfate resistance in cement concrete performed by Moskvin et al. (1980) showed that the main structural characteristics and performance of heavy concretes based on Portland cement depend on its compression strength, density, and the number and nature of pores.

Kreis and Nigol (1969) determined that there is a direct relationship between the water absorption coefficient and corrosion resistance of samples produced based on shale ash, lime, and Portland cement. In their opinion, the greater the water content in the concrete mixture, the less its resistance to salt corrosion.

Studies addressing the properties of heavy silicate material showed that sulfate resistance depends not on density but on the internal structure of autoclaved concrete (Rooni, 1972). According to Ngo et al. (2020b), the resistance of heavy concrete in aggressive environments depends mainly on the morphology of cement hydrates, and density is less essential.

Table 4. Water tightness of B25 and B35 of heavy concretes based on the MV-D20 modified binder with the composite additive

Core sample No.	Concrete resistance to air penetration in accordance with the applicable regulatory document, s/cm^3	Actual value	Water tightness grade, W
Heavy concrete (B25)			
1	13.8–19.6	18.4	10
2	13.8–19.6	18.6	10
3	13.8–19.6	19.0	10
Heavy concrete (B35)			
4	19.7–29.0	25.2	12
5	19.7–29.0	24.4	12
6	19.7–29.0	26.6	12

Table 5. Sulfate resistance of B25 and B35 heavy concretes based on the MV-D20 modified binder with the composite additive

Relative deformation, % (in a month)											
1	2	3	4	5	6	7	8	9	10	11	12
B35 heavy concrete based on cement CEM I 42.5N CC (ordinary curing) (without additive)											
0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.06	0.07	0.08	0.09	0.097
B25 heavy concrete based on MV-D20											
0.01	0.02	0.02	0.03	0.04	0.05	0.06	0.06	0.07	0.08	0.085	0.095
B35 heavy concrete based on MV-D20											
0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.05	0.06	0.07	0.08	0.085

The sulfate resistance of the heavy concrete specimens was determined in accordance with State Standard GOST R 56687-2015 “Protection of Concrete and Reinforced-Concrete Constructions from Corrosion. Test Method of Sulfate Resistance of Concrete”. Table 5 presents the results of sulfate resistance tests involving B25 and B35 heavy concretes based on the MV-D20 modified binder with the composite additive

The relative deformation of B35 concrete based on sulfate-resistant Portland cement CEM I 42.5N SS (ordinary curing) by CaspiCement LLP at the age of 12 months during the tests is 0.097%. Concrete is classified as concrete of group III (sulfate-resistant) (Table 5). The application of the MV-D20 modified binder with the composite mineral additive instead of standard sulfate-resistant Portland cement CEM I 42.5N SS (ordinary curing) by CaspiCement LLP reduces the relative deformation of B35 concrete by 12%.

Conclusions

The experiments proved that the obtained B25 and B35 concretes based on the designed MV-D20 modified binder with the composite additive can be classified as concretes of group III (sulfate resistant) since the relative deformation of the samples at the age of 12 months is lower than the standard index of 0.1%.

It was established that the sulfate resistance of concrete can be improved by introducing into cement a composite mineral additive of optimal composition, consisting of tailings from the Balkhash Mining and Processing Plant, activated with microsilica.

The composite modifying additive of optimal composition, consisting of 60% tailings + 40% microsilica by mass is capable of binding $Ca(OH)_2$ into insoluble compounds, thus reducing the leaching rate of CaO. Besides, the composite mineral additive reduces the water absorption and increases the water tightness of concrete, and also reduces the relative deformation of B35 concrete by 12%.

References

Batrakov, V. G., Kaprielov, S. S., and Sheinfeld, A. V. (1989). Effectiveness of ultrafine wastes from the ferroalloy industry. *Concrete and Reinforced Concrete*, No. 8, pp. 24–25.

Bazhenov, Yu. M. (2002). *Concrete technology*. 3rd edition. Moscow: ASV, 499 p.

Guvalov, A. A., Abbasova, S. I., and Kuznetsova, T. V. (2017). Efficiency of modifiers when regulating properties of concrete mixes. *Stroitel'nye Materialy [Construction Materials]*, No. 7, pp. 49–51.

Kaprielov, S. S., Sheinfeld, A. V., and Krivoborodov, Yu. R. (1992). Impact of the structure of cement stone with microsilica and superplasticizer on the properties of concrete. *Concrete and Reinforced Concrete*, No. 7, pp. 4–7.

Kreis, U. and Nigol, T. (1969). Indirect assessment of the corrosion resistance of concretes by their physical structure. In: *Methods for the analysis of the resistance of building materials and structures*. Minsk: Vysshaya Shkola, pp. 117–124.

Lothenbach, B., Matschei, T., Möschner, G., and Glasser, F. P. (2008). Thermodynamic modelling of the effect of temperature on the hydration and porosity of Portland cement. *Cement and Concrete Research*, No. 38, Issue 1, pp. 1–18. DOI: 10.1016/j.cemconres.2007.08.017.

Lothenbach, B. and Winnefeld, F. (2006). Thermodynamic modelling of the hydration of Portland cement. *Cement and Concrete Research*, Vol. 36, Issue 2, pp. 209–226. DOI: 10.1016/j.cemconres.2005.03.001.

Moskvin, V. M., Ivanov, F. M., Alekseyev, S. N., and Guzeyev, Ye. A. (1980). *Corrosion of concrete and reinforced concrete. Methods of their protection*. Moscow: Stroyizdat, 536 p.

Nesvetayev, G. V. (2006). Effectiveness of superplasticizers in concretes. *Stroitel'nye Materialy [Construction Materials]*, No. 10, pp. 23–26.

Ngo, V. T., Lam, T. Q. K., Do, T. M. D., and Nguyen, T.-C. (2020a). Increased plasticity of nano concrete with steel fibers. *Magazine of Civil Engineering*, Issue 93 (1), pp. 27–34. DOI: 10.18720/MCE.93.3.

Ngo, X. H., Tang, V. L., Bulgakov, B. I., Aleksandrova, O. V., and Larsen, O. A. (2020b). Effect of organo-mineral additives on physical-mechanical properties and corrosion resistance of sand-cement mortars. *Construction: Science and Education*, Vol. 10, Issue 1 (35). DOI: 10.22227/2305- 5502.2020.1.5.

Rooni, I. (1972). On the sulfate resistance of heavy silicate concrete. In: *Durability of structures made of autoclaved concrete*. Tallinn, pp. 344–350.

Singh, N. B., Kalra, M., and Saxena, S. K. (2017). Nanoscience of cement and concrete. *Materials Today: Proceedings*, Vol. 4, Issue 4, Part E, pp. 5478–5487. DOI: 10.1016/j.matpr.2017.06.003.

Slavcheva, G. S., Artamonova, O. V., Shvedova, M. A., and Khan, M. A. (2020). Clinkerless slag-silica binder: hydration process and hardening kinetics (part 2). *Magazine of Civil Engineering*, Issue 97 (5), 9712. DOI: 10.18720/MCE.97.12

Tang, V. L., Bulgakov, B. I., Alexandrova, O. V., and Larsen, O. A (2017). Possibility of using bottom ash for manufacturing building materials in Vietnam. *Bulletin of BSTU named after V. G. Shukhov*, No. 6, pp. 6–12. DOI: 10.12737/article_5926a059214ca0.89600468.

Yestemessova, A. S., Altayeva, Z. N., Sarsenbayev, B. K., Budikova, A. M., and Karshygayev, R. O. (2020). Modifying additive for concrete based on shungite processing waste. *IOP Conference Series: Materials Science and Engineering*, Vol. 945, 012042. DOI: 10.1088/1757-899X/945/1/012042.

Zhakipbekov, Sh. K., Aruova, L. B., Toleubayeva, Sh. T., Ahmetganov, T. B., and Utkelbaeva, A. O. (2021a). The features of the hydration and structure formation process of modified low-clinker binders. *Magazine of Civil Engineering*, Issue 103 (3), 10302. DOI: 10.34910/MCE.103.2.

Zhakipbekov, Sh. K., Yestemessova, A. S., and Zhilkibayeva, A. (2021b). Physico-mechanical properties of heavy concrete with a complex mineral additive. *The Scientific Journal of the Modern Education & Research Institute*, Issue 16, pp. 71–76.

Zhakipbekov, Sh. K., Zhilkibayeva, A. M., Toleubayeva, Sh. B., and Danenova, G. T. (2020). *Patent No. 5430 (Republic of Kazakhstan). Binding mixture based on tailings.*

Zhang, P., Ou, L., and Liu, K. (2016). Hydration mechanism of Portland cement prepared from stonecoal vanadium slag. *Procedia Environmental Sciences*, Vol. 31, pp. 598–604. DOI: 10.1016/j.proenv.2016.02.102.

Zhilkibaeva, A. M. and Estemesova, A. S. (2020). Investigation of the process of hardening and structure formation of concrete using modified binders. *Bulletin of Kazakh Leading Academy of Architecture and Construction*, No. 4 (78), pp. 163–168.

Zhilkibayeva, A. M. (2021). Technological methods for increasing the activity of mineral admixtures. In: Gulyayev, G. Yu. (ed.) *Proceedings of the 5th International Scientific Conference "Modern Science and Young Scientists"*. Penza: Science and Education, pp. 36–38.

Zhilkibayeva, A. M., Yestemessova, A. S., Zhakipbekov, Sh. K., Matveeva, L. Yu., and Morozov, V. I. (2021). Th*e effect of a complex mineral supplement on the hydration of alite.* ALITinform: Cement. Concrete. Dry Mixtures, No. 3 (64), pp. 84–92.

Zvezdov, A. I. and Mikhailov, K. V. (2001). 21st century — the century of concrete and reinforced concrete. *Concrete and Reinforced Concrete*, No. 1, pp. 2–6.

СТРОИТЕЛЬНО-ЭКСПЛУАТАЦИОННЫЕ ХАРАКТЕРИСТИКИ БЕТОНА С КОМПЛЕКСНОЙ МОДИФИЦИРУЮЩЕЙ ДОБАВКОЙ

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Аннотация

Рассмотрено влияние комплексной модифицирующей минеральной добавки на основе отходов – хвостов обогащения Балхашского горно-обогатительного комбината с микрокремнеземом на строительно-эксплуатационные свойства тяжёлого бетона. **Целью работы** был подбор оптимальных составов бетонов класса В 25 и В 35 на основе полученного модифицированного вяжущего МВ-Д20 с комплексной добавкой в его составе и оценка характеристик бетонов. **Методы:** Проектирование составов и испытания характеристик бетона проводили **стандартными методами.** Подбор состава бетона выполнен согласно ГОСТ 27006-86 «Бетоны. Правила подбора состава». Физико-механические свойства тяжёлого бетона определяли по ГОСТ 10180-2012 «Бетоны. Методы определения прочности по контрольным образцам». Оценку прочности проводили по ГОСТ 18105-2018 «Бетоны. Правила контроля и оценки прочности». **Результаты:** Установлено, что разработанные составы тяжелых бетонов по скорости набора прочности относятся к быстротвердеющим. Бетоны в начальном сроке твердения 7 суток набирают 90,1 и 85,4 %, соответственно, требуемой нормативной прочности. Средние значения показателя водопоглощения бетонов класса В 25 и В 35, соответственно, составляют 4,20 и 3,46 %. Марки бетонов по водонепроницаемости соответствуют W10 и W12. Применение полученного модифицированного вяжущего МВ-Д20 с комплексной добавкой на основе отходов хвостов обогащения и микрокремнезема в его составе взамен базового сульфатостойкого портландцемента позволяет снизить относительную деформацию бетона класса В 35 в агрессивной среде на 12%.

Ключевые слова

Комплексная минеральная добавка, сульфатостойкий портландцемент, отходы – хвосты обогащения, микрокремнезем, прочность, быстротвердеющий бетон, водопоглощение, водонепроницаемость.