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РАЗРАБОТКА СВОЙСТВ ВЯЖУЩИХ ВЕЩЕСТВ С ПОМОЩЬЮ МИНЕРАЛЬНЫХ И ХИМИЧЕСКИХ ДОБАВОК

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Аннотация. В статье приведены результаты научно-исследовательских работ по разработке свойств вяжущих веществ с комплексно-минеральными и одновременно химическими добавками и определены оптимальные составы. Применение отходов местной промышленности в качестве вторичного сырья при производстве новых и современных видов строительных материалов, а именно минеральных мелкодисперсных добавок, обеспечение формирования плотной и прочной структуры бетонной смеси, достигающей таких свойств, как прочность, морозоустойчивость, без оказания негативного влияния добавок на процесс гидратации цемента, на свойства вяжущего, что является одной из самых главных и актуальных в настоящее время областей исследований [1–12]. На сегодняшний день – наряду с водой, наполнителем и вяжущим – обязательным компонентом бетонной смеси стали добавки. Среди множества видов химических добавок отдельное место занимают пластификаторы, особенно самые эффективные из них – суперпластификаторы [1–12].Что касается местной строительной практики, следует отметить, что использование суперпластификатора в технологии строительства монолитных зданий в стране находится на очень низком уровне. Это можно объяснить тем, что, во-первых, в Узбекистане производится мало химических добавок для целевого бетона, в том числе суперпластификаторов, а во-вторых, также очень актуальным вопросом является проведение сравнительных исследований имеющихся в продаже суперпластификаторов и разработка рекомендаций по их практическому применению.

Ключевые слова: комплексные добавки, промышленные отходы, вторичные материалы, зола-унос, отходы медеплавильной промышленности, химические добавки, прочность, долговечность

РОЗРОБКА ВЛАСТИВОСТЕЙ В'ЯЖУЧИХ РЕЧОВИН ЗА ДОПОМОГОЮ МІНЕРАЛЬНИХ І ХІМІЧНИХ ДОБАВОК

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Анотація. У статті наведені результати науково-дослідних робіт з розробки властивостей в'яжучих речовин з комплексно-мінеральними і водночас хімічними добавками і визначені оптимальні склади. Застосування відходів місцевої промисловості як вторинної сировини при виробництві нових і сучасних видів будівельних матеріалів, а саме мінеральних дрібнодисперсних добавок, забезпечення формування щільної і міцної структури бетонної суміші, що набуває таких властивостей, як міцність, морозостійкість, без надання негативного впливу добавок на процес гідратації цементу , на властивості в'яжучого, що є однією з найголовніших і актуальних в даний час областей досліджень [1–12]. На сьогодні – поряд з водою, наповнювачем і в'яжучим – обов'язковим компонентом бетонної суміші стали

добавки. Серед безлічі видів хімічних добавок окреме місце займають пластифікатори, особливо найефективніші з них – суперпластифікатори [1–12] Що стосується місцевої будівельної практики, слід зазначити, що використання суперпластифікатора в технології будівництва монолітних будівель в країні знаходиться на дуже низькому рівні. Це можна пояснити тим, що, по-перше, в Узбекистані виробляється мало хімічних добавок для цільового бетону, у тому числі суперпластифікаторів, а по-друге, також дуже актуальним питанням є проведення порівняльних досліджень наявних у продажу суперпластифікаторів і розробка рекомендацій щодо їх практичного застосування.

Ключові слова: комплексні добавки, промислові відходи, вторинні матеріали, зола-винесення, відходи мідьоплавильної промисловості, хімічні добавки, міцність, довговічність.

DEVELOPMENT OF PROPERTIES OF BINDERS WITH THE HELP OF MINERAL AND CHEMICAL ADDITIVES

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Abstract. The article presents the results of research work on the development of properties of binders with complex-mineral and at the same time chemical additives and the optimal compositions are determined. The use of local industrial waste as a secondary raw material in the production of new and modern types of building materials, namely fine mineral additives, ensuring the formation of a dense and durable structure of the concrete mixture, which achieves properties such as strength, frost resistance, without adversely affecting the cement hydration process, on the properties of a binder is one of the most important and relevant research areas at present[1–12]. Today, along with water, filler and binder, additives have become an indispensable component of the concrete mix. Among the many types of chemical additives, plasticizers occupy a separate place, especially the most effective of them – super plasticizers [1–12]. With regard to local construction practice, it should be noted that the use of super plasticizer in monolithic building technology is very low in the country. This can be explained by the fact that, firstly, in Uzbekistan, few chemical additives are produced for target concrete, including super plasticizers, and secondly, it is also a very urgent issue to conduct comparative studies of commercially available super plasticizers and develop recommendations for their practical use.

Keywords: complex additives, industrial waste, secondary materials, fly ash, copper-smelting industry waste, chemical additives, strength, durability.

The increase in promising types of binders is due to the use of active mineral additives that arise in natural and man-made conditions. To ensure the activity of the structure of concrete and concrete mixture, together with chemical additives, it is also advisable to add powders of various mineral rocks related to mineral additives, materials obtained in natural or man-made conditions: ash from thermal power plants, metallurgical slags and additives from various rocks.

One of the most important properties of ash as an active mineral additive in concrete is its hydraulic activity. Traditionally, it is determined by the ability of ash to absorb lime from a lime solution and to exhibit astringent properties in combination with hydrated lime. The microcalorimetric method is a new method for determining the activity of ash: the activity of ash is determined by the value of the heat of its wetting in polar and non-polar liquids. This takes into account the coefficient of hydrophilicity

and other parameters [2].

For certain types, ash classes for concrete are additionally distinguished:

A (heavy) – the specific surface of the ash must be at least 2 800 cm^2/g;

B (light) – 1 500 ... 4 000 cm^2/g.

The residue on sieve № 008 for class A ash should not exceed 15%.

The selection of the composition of concrete with the addition of ash consists in determining such a ratio of components at which the characteristics of the concrete mixture and concrete would be achieved with a minimum consumption of cement. In the concrete mixture, ash plays the role of not only an active mineral additive that increases the amount of binder, but also the function of a micro-filler, which improves the granulometry of sand and actively affects the processes of structure formation of concrete [2].

Given the semi-functional nature of the entire additive, its introduction instead of a part of cement or sand does not make it possible to solve the problem of optimizing the composition.

Reducing the consumption of cement when adding ash is advisable first of all in the case of excessive activity of cement, that is, when the cement grade is higher than the recommended one. When using TPP ash, it is allowed to reduce the minimum typical cement consumption for unreinforced concrete products to 150 kg/m^3, and for reinforced concrete products to 180 kg/m^3. In this case, the total consumption of cement and ash must be at least 200 and 220 kg/m^3, respectively. The amount of ash should be determined in proportion to the required reduction of the Excessive activity of the cement [3].

Adding ash in an optimal amount does not increase the water consumption of concrete mixes, which is explained by the melting of particles and their relatively regular shape. With a high dispersion of ash and an insignificant content of unburned coal in it, the workability of the mixture increases. The plasticizing effect of ash increases if there is a fine aggregate in the concrete mixture with an insufficient amount of fine fractions.

The introduction of fly ash from the combustion of lignite and bituminous coals into sandy concrete avoids excessive consumption of cement.

To achieve high strength of ash-containing concrete, the chemical and mineralogical composition of clinker is of certain importance. At an early age, the growth of concrete strength is facilitated by the increased content of alkalis in the clinker, which accelerate the chemical interaction of ash and cement; in the later, for the manifestation of the pozzolanic reaction of ash, cements with a high alite content are preferable, since during hydrolysis they form $Ca(OH)_2$ [3].

Like other hydraulic additives, ash reduces the frost resistance and heat resistance of concrete. The possibility of using ash in concretes with frost resistance F50 and higher is established by special studies. The decrease in the frost resistance of concrete can be compensated by the introduction of air-entraining additives.

Due to the relatively low water demand of concrete mixtures, the replacement of up to 20 % of cement with ash has practically no effect on the shrinkage deformations of concrete when it is hardened in air.

Ash-containing concretes are distinguished by high sulfate resistance, good results are achieved with the introduction of ash containing more than 80 % $(Cu_2 + Al_2O_3)$.

Fly-ash. Provides in the manufacture of concrete mixes and concrete the availability and strength of concrete without deterioration of its physical, chemical and mechanical properties, along with saving the amount of binder, rational use of heat energy when used together with Portland cement, increasing the efficiency of using secondary resources, reclamation and disposal of land contaminated with industrial waste [4].

Fly-ash is a dusty material that is captured from the flue gases of TPPs using cyclones and electrostatic precipitators. The ash particle size ranges from 3–5 to 100–150 microns. The number of large particles does not exceed 10–15 %. Average density of ash is 2–2,5 g/cm^3, bulk density is 0,5–0,8 g/cm^3. One of the most important properties of ash as an active mineral additive in concrete is its hydraulic activity. Traditionally, it is determined by the ability of ash to absorb lime from a lime solution. Improves water permeability; reduces the water-cement ratio and increases the durability of concrete; does not contain chlorine and other components that can cause corrosion when used in reinforced concrete. Suitable for use in reinforced concrete [4].

Waste from the copper smelting industry. In the manufacture of concrete mixes and concrete, they ensure the availability and strength of concrete

Table 1. Chemical composition of fly ash

Name	Number of oxides, mass% by mass							
Fly-ash	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	CO_3	Na_2O+K_2O	Total
	35,80	18,45	15,30	18,30	4,15	3,80	3,7	100,0

Table 2. Influence of fly ash on the properties of Portland cement

№	Portland cement amount (gr)	Sand (gr)	Water (ml)	W/C (%)	Additive amount (%)	Strength	
						Bend, MPa	Compression, MPa
1	500	1 500	200	0,4	0	10,81	31,89
2	450	1 500	200	0,4	10	10,8	31,5
3	400	1 500	200	0,4	20	10,0	30,6
4	350	1 500	200	0,4	30	9,1	27

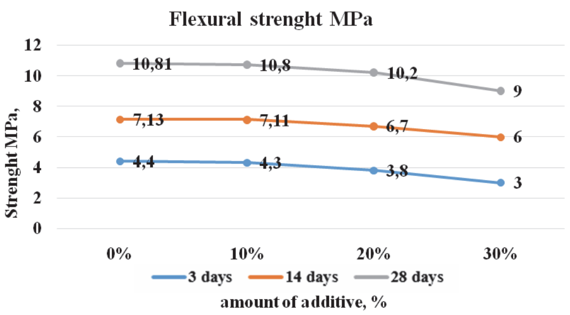

Figure 1. Influence of fly ash on bending properties of Portland cement.

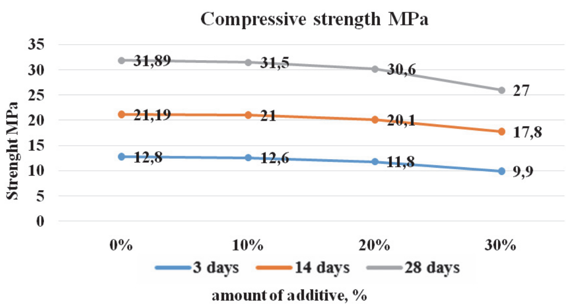

Figure 2. Influence of fly ash on the properties of Portland cement in compression.

without deteriorating its physical, chemical and mechanical properties, along with saving the amount of binder, rational use of heat energy when used together with Portland cement, increasing the efficiency of using secondary resources, reclamation and disposal of land contaminated with industrial waste.

The state of the waste, fired solid, slag, is characterized by a large amount of iron in the composition. After the metal is separated from the composition of this waste, it can also be used as sand or crushed stone. The slag of copper smelting is dark in color, water demand does not exceed 0,6 %, the melting point is 990–1 175 °C. In terms of chemical composition, it is acidic and basic. Bulk density – 1,8 t/ m^3. Fraction from 2–5 to 0,25–0,5 mm. For example, granulated slags from the copper processing industry served as raw materials for binding materials for the manufacture of concrete of various grades, hardened in autoclaves [4].

The above table shows the values in MPa of the flexural and compressive strength of a 3-, 14- and 28-day cement mix made with the addition of a complex of fly ash and copper smelter waste as a mineral additive.

The above table shows the values of the flexural and compressive strengths of cement mixture samples made with the addition of fly ash and copper-smelting waste, based on these data, the optimal composition of the cement mixture with the addition of two mineral additives was selected. In the case when 15 % fly ash and 5 % copper smelter additive were added, and the total cement consumption (from the amount of binder) was changed by

Table 3. Chemical composition of copper-smelting waste

Name	Number of oxides, mass% by mass							
Copper-smelting waste	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	CO_3	Na_2O+ K_2O	Total
	35,80	18,45	15,30	18,30	4,15	3,80	3,7	100,0

Table 4. Influence of copper smelter waste on the properties of Portland cement

№	Portland cement amount (gr)	Sand (gr)	Water (ml)	W/C (%)	Additive amount (%)	Strength	
						Bend, MPa	Compression, MPa
1	500	1 500	200	0,4	0	9,5	28,25
2	450	1 500	200	0,4	5	9,2	28,1
3	400	1 500	200	0,4	10	8,7	27,4
4	350	1 500	200	0,4	15	8	25,7

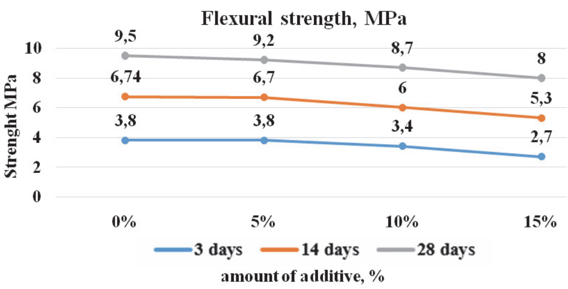

Figure 3. Influence of waste from the copper smelting industry on the bending properties of Portland cement.

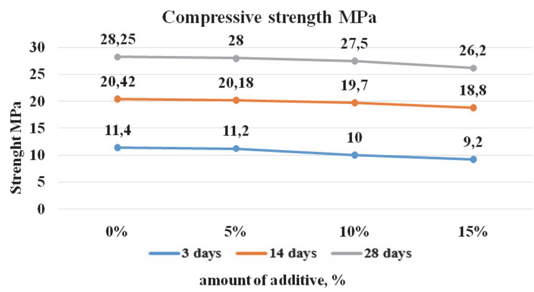

Figure 4. Influence of waste from the copper smelting industry on the properties of Portland cement in compression.

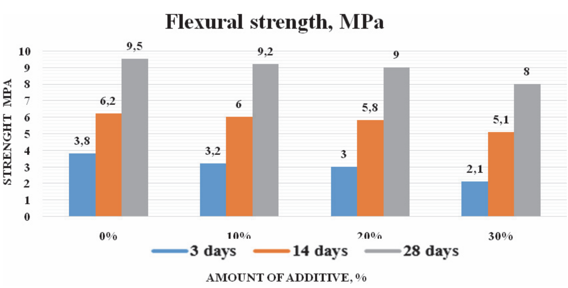

Figure 5. Influence on the flexural strength of specimens made with the addition of a complex of fly ash and copper smelter waste.

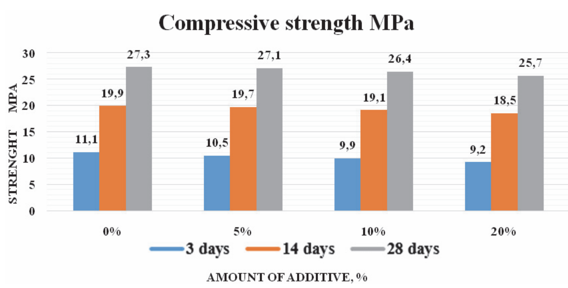

Figure 6. Influence on the compressive strength of samples made with the addition of a complex of fly ash and copper smelter waste.

20 %, the strength of the mixture was higher than that of fly ash alone with a change of 20 %.

The analysis of theoretical and practical works on this topic is carried out, the relevance of research work is studied. It is also related to the properties of the materials used in the production of high quality lightweight concrete. In this research work, the influence of materials used in the manufacture of

Table 5. Flexural and compressive strength of samples made with the addition of a complex of fly ash and copper smelter waste.

№	Portland cement amount (gr)	Sand (gr)	Water (ml)	W/C (%)	Additive amount (%)		Strength	
					Fly ash	Waste from the copper smelting industry	Bend, MPa	Compression, MPa
1	500	1 500	200	0,4	0	0	9,5	27,3
2	450	1 500	200	0,4	5	5	9,2	27,1
3	400	1 500	200	0,4	15	5	9	26,4
4	350	1 500	200	0,4	20	10	7,6	25,7

high-quality cement mixtures, mainly Portland cement, mineral additives (fly ash and waste from the copper industry), on the properties of fine fillers - sand, water and cement paste is studied [4].

After the selection of the optimal composition of the cement paste made with the addition of a complex of mineral additives, the properties of this mixture were studied with the addition of the superplasticizer «Beton Strong-17».

Superplasticizer «Beton Strong-17» is considered complex, thanks to this additive, the plasticity of the concrete mixture increases, its setting time is accelerated, and the concrete is given resistance to freezing. Superplasticizer «Beton Strong-17« is a complex additive designed for cold climates, which accelerates the hardening of the concrete mixture, gives concrete antifreeze properties and increases its plasticity.

Complex plasticized admixture in concrete and building mixtures «Beton Strong 17» with frost resistance effect consists of a mixture of sodium polynaphthalene methylene sulfonate and sodium formate.

Increases the mobility of the concrete mixture from P1 to P5, mortar – from PK1 to PK4 (strength does not decrease at all times of hardening) [5].

When mixed with water, the superplasticizer reduces the water requirement of the mixture to 20–25 %.

Prevents freezing of concrete and mortar mixtures before the start of active heat treatment during the construction of concrete and reinforced concrete structures.

It prevents the mixture from freezing and the cessation of cement hydration processes in the event of forced periods of lack of heat treatment, significantly intensifies the strength gain upon subsequent exposure to positive temperatures [5].

It is effective for ensuring the transportation of concrete mixture at a temperature not lower than minus 25 °C with the condition of subsequent heat treatment of the erected structure. It is used as an anti-frost additive for warm floors at ambient temperatures up to minus 25 °C in accordance with GOST 24211-08 [6].

Provides the ability to reduce the heat treatment of concrete in comparison with multicomponent antifreeze additives.

In the course of studying the properties of BekabadPC400 and fly ash, using four different amounts of the chemical additive «Betong strong-17» in relation to the mass of cement, we selected the most optimal amount of the additive for us – 1 %.

In the course of scientific research, the effect of a chemical additive in a cement mixture made with the addition of a complex of binding mineral additives has been studied. With the addition of a chemical additive, the cement mixture acquired approximately 65–70 % of the required strength in 3 days. As a result of accelerating the hardening time of the cement mixture with this additive, the strength also increased. The indicators of economic efficiency have been determined: the consumption of cement per 1 m^3 of concrete is 400 kg, with the complex use of mineral additives, 20 % of the amount of binder can be saved by changing its composition, and not the amount of the binder, and the use of the chemical additive «Beton Strong-17» reduced the consumption of the binder (Portland cement) by 20 % and provided the required strength.

Table 6. Influence of the superplasticizer «Beton Strong-17» on the properties of Portland cement

№	Portland cement amount (gr)	Sand (gr)	Water (ml)	W/C (%)	Additive amount (%)	Strength	
						Bend, MPa	Compression, MPa
1	500	1 500	200	0,4	0	5,6	40,5
2	500	1 500	185	0,37	1	7,3	52

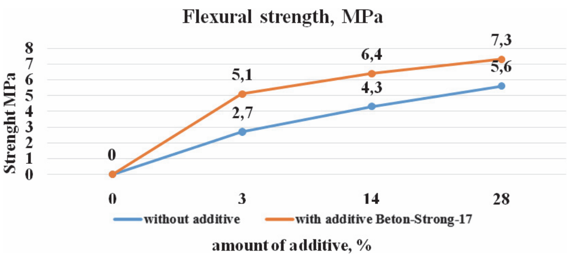

Figure 7. Influence of the superplasticizer «Beton Strong-17» on the properties of Portland cement.

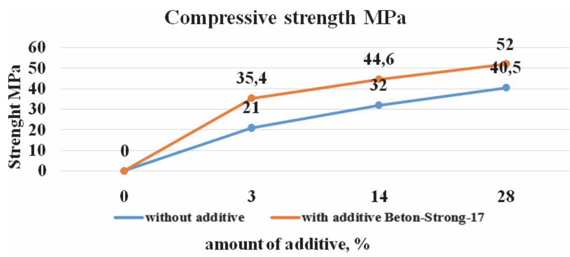

Figure 8. Influence of the superplasticizer «Beton Strong-17» on the properties of Portland cement.

Table 7. Influence of the superplasticizer «Beton Strong-17» on the properties of Portland cement

№	Portland cement amount (gr)	Sand (gr)	Water (ml)	W/C (%)	Additive amount (%)	Strength	
						Bend, MPa	Compression, MPa
1	500	1 500	200	0,4	0	5,3	39,8
2	400	1 500	128	0,32	1,0	5,6	40,5

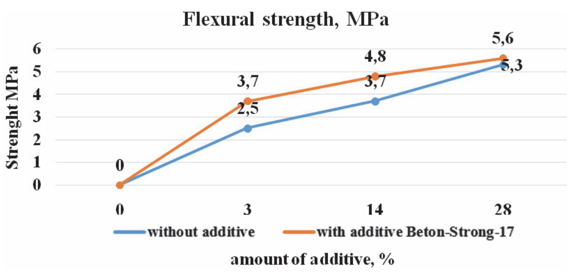

Figure 9. Influence of the superplasticizer «Beton Strong-17» on the properties of Portland cement.

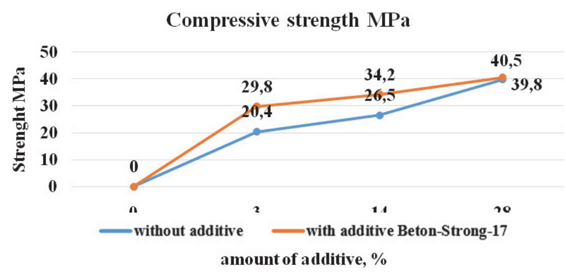

Figure 10. Influence of the superplasticizer «Beton Strong-17» on the properties of Portland cement.

At the same time: the price of 1 kg of Portland cement is 780 sum, 1 m^3 of concrete requires 400 kg of Portland cement, the cost for this amount is 312,000 sum. The price of 1 kg of fly ash is 35 sum, with the introduction of 15 % of the amount of binder, 60 kg of fly ash will be required, its cost will be 2,100 sum. And the price of 1 kg of waste from the copper industry is 25 sum, with the introduction of them in the amount of 5 % of the total amount of binder, the cost of 20 kg of industrial copper waste will be 500 sum.

In turn, the cost of a binder (Portland cement) per 1 m^3 of concrete is 312,000 sum, and the cost of a complex binder based on mineral additives is: 80 kg

Table 8. Influence on the properties of Portland cement of mineral additives in the binder in the form of a complex of fly ash and copper industrial waste and superplasticizer «Beton Strong-17»

№	Binder amount (gr)			Sand (gr)	Water (ml)	W/C (%)	Additive amount (%)	Strength	
	Portland cement 80 %	Fly-ash 15 %	Waste from the copper industry 5 %					Bend, MPa	Compression, MPa
1	500			1 500	200	0,4	0	4,9	39,4
2	400			1 500	128	0,32	1,0	5,7	41,9

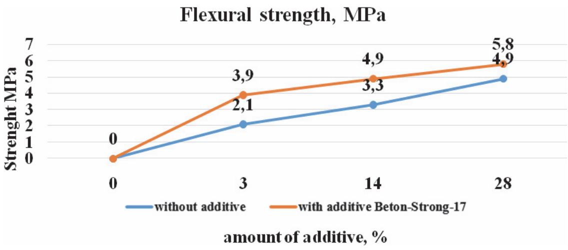

Figure 11. Influence of mineral additives and superplasticizer «Beton Strong-17» on the properties of Portland cement.

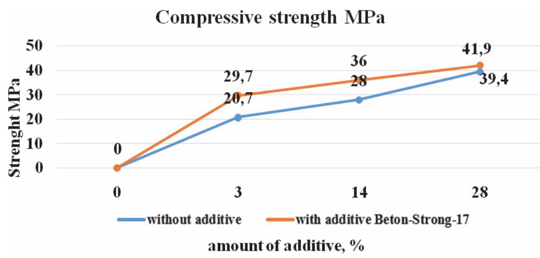

Figure 12. Influence of mineral additives and superplasticizer «Beton Strong-17» on the properties of Portland cement.

of Portland cement – 62,400 sum, 80 kg of mineral additives – 2,600 sum, of which 60 kg of fly ash – 2,100 sum, 20 kg of waste from the copper industry – 500 sum (312,000–62 400 = 249 600 sum. When adding the cost of mineral additives (2 600 sum) to the price of this Portland cement (249 600 sum), the total cost will be 252 200 sums. The indicator of the economic efficiency of the mineral additive from the cost of the binder material (Portland cement) for each 1 m^3 of concrete amounted to 59 800 sum.

With the addition of a chemical additive, we save 20 % of 400 kg of binder used to make 1 m^3 of concrete, if 252,200 sum were spent on a complex binder containing mineral additives, then this cost is further reduced by 11 240 sum (20 %). Moreover, if the price of 1 kg of a chemical additive is 9 800 sum, the cost per 1 m^3 of concrete will be 39,200 sum. The general indicator of economic efficiency when using together mineral and chemical additives was due to the cost of the binder 71 040 sum per 1 m^3 of concrete.

The addition of a complex of mineral additives and a chemical additive Beton Strong-17 increases the durability, strength and frost resistance of concrete, allowing it to work even at temperatures of 0...–10 °C.

This study is relevant, designed to improve the performance properties of building cement mixtures by adding chemical and complex modifying mineral active additives based on industrial waste proposed by the author.

Литература

1. Газиев, У. А. Отходы промышленности в производстве строительных материалов и изделий / У. А. Газиев. – Ташкент : ТАСИ, 2015. – 308 с. – Текст : непосредственный
2. Газиев, У. А. Отходы промышленности Республики Узбекистан в производстве эффективных

Reference

1. Gaziyev, U. A. Industrial waste in the production of building materials and products. – Tashkent : TIACE, 2015. – 308 p. – Text : direct. (in Russian)
2. Gaziyev, U. A.; Rakhimov, Sh. T.; Kurbonov, F. T. Industrial waste of the Republic of Uzbekistan in the production of effective building materials. –

строительных материалов / У. А. Газиев, Ш. Т. Рахимов, Ф. Т. Курбонов. – Текст : непосредственный // Проблемы и перспективы развития инновационного сотрудничества в научных исследованиях и системе подготовки кадров : материалы международной научно-практической конференции, [Бухара, 2017 г.]. – Бухара : БухМТИ, 2017. – С. 117–118.
3. Shakirov, T. T. Studies of the phase composition and structure formation of porous aggregate / T. T. Shakirov. – Текст : электронный // International Journal for Innovative Research in Multidisciplinary Field. – 2019. – Volume 5, Issue 8. – ISSN 2455-0620. – P. 151–155. – URL: https://www.ijirmf.com/wp-content/uploads/IJIRMF201908026.pdf (дата обращения: 20.05.2020).
4. Мўминова, Н. А. Минерал қўшимчалар ёрдамида бетон хоссаларини яхшилаш : магистрлик диссертацияси / Мўминова Нилуфар Абдулла қизи; Ташкентский архитектурно-строительный институт. – Ташкент, 2019. – 130 с. – Текст : непосредственный.
5. Шакиров, Т. Т. Технология получения пористого заполнителя из кварцевого порфира и отхода угледобычи для легкого бетона : автореферат диссертации на соискание ученой степени кандидата технических наук / Шакиров Туйғун Турғунович ; Ташкентский архитектурно-строительный институт. – Ташкент, 2010. – 21 с. – Текст : непосредственный.
6. Effect of Relamix additive on cement properties / U. A. Gaziev, X. A. Akramov, T. T. Shakirov, Sh. T. Rakhimov. – Текст : электронный // International Journal for Innovative Research in Multidisciplinary Field. – 2019. – Volume 5, Issue 8. – ISSN 2455-0620. – P. 163–165. – URL: https://www.ijirmf.com/wp-content/uploads/IJIRMF201908029.pdf (дата обращения: 25.05.2020).
7. Ресурсо- и энергосберегающие технологии получения пористого заполнителя для легких бетонов / У. А. Газиев, Х. А. Акрамов, Т. Т. Шакиров, Ш. Т. Рахимов. – Текст : непосредственный // Современное состояние и перспективы развития строительства, теплогазоснабжения и энергообеспечения : материалы VI Международной научно-практической конференции, Саратов, 9–10 ноября 2017 ; Саратовский государственный аграрный университет им. Н. И. Вавилова. – Саратов : Издательство Амирит, 2017. – С. 66–69.
8. Оценка влажностного режима многослойной стеновой конструкции в годовом цикле / С. В. Корниенко, Н. И. Ватин, М. Р. Петриченко, А. С. Горшков. – Текст : электронный // Строительство уникальных зданий и сооружений. – 2015. – Выпуск 6(33). – С. 19–33. – ISSN 2304-6295. – URL: https://unistroy.spbstu.ru/userfiles/files/2015/6(33)/2_korniyenko_33.pdf (дата обращения: 25.08.2020).
9. Копылова, А. И. Влажностный режим ограждающей конструкции с облицовкой силикатным кирпичом / А. И. Копылова, А. К. Богомолова,

Text : direct. – In: *Problems and prospects for the development of innovative cooperation in scientific research and the system of personnel training: materials of the international scientific and practical conference*. – Bukhara: BukhMTI, 2017. – P. 117–118. (in Russian)
3. Shakirov, T. T. Studies of the phase composition and structure formation of porous aggregate. – Text : electronic. – In: I*nternational Journal for Innovative Research in Multidisciplinary Field*. – 2019. – Volume 5, Issue 8. – ISSN 2455-0620. – P. 151–155. – URL: https://www.ijirmf.com/wp-content/uploads/IJIRMF201908026.pdf (date of access: 20.05.2020). (in English)
4. Muminova, N. A. Improving the properties of concrete with mineral additives : Master's Thesis. – Tashkent, 2019. – 130 p. – Text : direct. (in Russian)
5. Shakirov, T. T. Technology for producing porous aggregate from porphyry silica and coal waste for lightweight concrete : abstract of thesis of Ph. D. in Engineering ; TACEI. – Tashkent, 2010. – 21 p. – Text : direct. (in Russian)
6. Gaziev, U. A.; Akramov, X. A.; Shakirov, T. T.; Rakhimov, Sh. T. Effect of Relamix additive on cement properties. – Text : electronic. – In: I*nternational Journal for Innovative Research in Multidisciplinary Field*. – 2019. – Volume 5, Issue 8. – ISSN 2455-0620. – P. 163–165. – URL: https://www.ijirmf.com/wp-content/uploads/IJIRMF-201908029.pdf (date of the access: 25.05.2020). (in English)
7. Gaziyev, U. A.; Akramov, Kh. A.; Shakirov, T. T.; Rakhimov, Sh. T. Resource and energy saving technologies for producing porous aggregate for lightweight concrete. – Text : direct. – In: *The current state and prospects for the development of construction, heat and gas supply and energy supply* : materials of the VI International scientific and practical conference. – Saratov : Amirit Publishing House, 2017. – P. 66–69. (in Russian)
8. Korniyenko, S. V.; Vatin, N. I.; Petrichenko, M. R.; Gorshkov, A. S. Assessment of the moisture regime of a multilayer wall structure in the annual cycle. – Text : electronic. – In: C*onstruction of unique buildings and structures*. – 2015. – Issue 6(33). – P. 19–33. – ISSN 2304-6295. – URL: https://unistroy.spbstu.ru/userfiles/files/2015/6(33)/2_korniyenko_33.pdf (date of access: 25.08.2020). (in Russian)
9. Kopylova, A. I.; Bogomolova, A. K.; Nemova, D. V. Humidity regime of the enclosing structure with silicate brick cladding. – Text : electronic. – In: *Construction of unique buildings and structures*. – 2015. – Issue 6(33). – P. 74–86. – ISSN 2304-6295. – URL: https://unistroy.spbstu.ru/userfiles/files/2015/6(33)/6_kopylova_33.pdf (date of access: 25.05.2020). (in Russian)
10. Shakirov, T. T. Porous aggregate for lightweight concrete based on local raw materials. – Text : electronic. – In: *Scientific readings in memory of the associate professor of the department of technologies*

Д. В. Немова. – Текст : электронный // Строительство уникальных зданий и сооружений. – 2015. – Выпуск 6(33). – С. 74–86. – ISSN 2304-6295. – URL: https://unistroy.spbstu.ru/userfiles/files/2015/6(33)/6_kopylova_33.pdf (дата обращения: 25.05.2020).
10. Шакиров, Т. Т. Пористый заполнитель для легких бетонов на основе кварцевого порфира и отхода угледобычи / Т. Т. Шакиров. – Текст : непосредственный // Химия и химическая технология: достижения и перспективы: материалы IV Всероссийской конференции, Кемерово, 27–28 ноября 2018. – Кемерово : ФГБОУ ВО «Кузбасский государственный технический университет имени Т. Ф. Горбачева». – С. 528.1–528.4.
11. Влияние добавок и продолжительности помола на степень белизны цемента / Аг. А. Мухамедбаев, А. А. Тулаганов, Х. Х. Камилов [и др.]. – Текст : непосредственный // Научно-практический журнал «Архитектура. Строительство. Дизайн». – Ташкент : ИздательствоТАСИ, 2014. – № 3. – С. 24–28.
12. Патент № SU 1574565 A1 Союз Советских Социалистических Республик, МПК C04B 24/18. Комплексная добавка в строительный раствор и бетонную смесь : № 4349725/31-33 : заявл. 25.12.1987 : опубл. 30.06.1990 / Тулаганов А. А., Касимов И. К., Дустов Р. Д., Соломатов В. И., Фарбман Л. И., Ханин В. К., Алиев А. Г., Рубинштейн А. И., Юсупов П. П., Камилов Х. Х., Халикеев Н. К. ; заявитель Ташкентский политехнический институт им. А. Р. Бируни. – 3 с. – Текст : непосредственный.

of building structures, products and materials Alexander Dmitrievich Lazko : materials of the international conference. – Makeevka : DNACEA, 2019. – P. 32. – URL: http://donnasa.ru/publish_house/journals/studconf/2018/Nauchnie%20chtenia_2018.pdf (date of access: 05.01.2019). (in Russian)
11. Mukhamedbayev, Ag. A.; Tulaganov, A. A.; Kamilov, Kh. Kh. [et. al.]. The effect of additives and the duration of grinding on the degree of whiteness of cement. – Text : direct. – In: *Scientific and practical journal «Architecture. Building. Design»*. – Tashkent : TIACE, 2014. – № 3. – P. 24–28. (in Russian)
12. Patent № SU 1574565 A1 Union of Soviet Socialist Republics, MPK C04B 24/18. Complex additive in mortar and concrete mix : № 4349725/31-33 : declaration 25.12.1987 : published 30.06.1990 / Tulaganov A. A., Kasimov I. K., Dustov R. D., Solomatov V. I., Farbman L. I., Khanin V. K., Aliyev A. G., Rubinshteyn A. I., Yusupov P. P., Kamilov Kh. Kh., Khalikeyev N. K.; applicant A. R. Biruni Tashkent Polytechnic Institute. – 3 p. – Text : direct. (in Russian)

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