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DEVELOPED MODIFIED ADDITIVE IMPACT EVALUATION ON THE CONCRETE STRENGTH CHARACTERISTICS

ӘЗІРЛЕНГЕН МОДИФИКАЦИЯЛАНҒАН ҚОСПАНЫҢ БЕТОННЫҢ БЕРІКТІК СИПАТТАМАЛАРЫНА ӘСЕРІН БАҒАЛАУ

ОЦЕНКА ВЛИЯНИЯ РАЗРАБОТАННОЙ МОДИФИЦИРОВАННОЙ ДОБАВКИ НА ПРОЧНОСТНЫЕ ХАРАКТЕРИСТИКИ БЕТОНА

Abstract. *The article represents of the laboratory researches of the complex modified additive impact, especially effect of variable value components of the additive on concrete strength characteristics. This article is dedicated a solution of the problem of enhancement operating characteristics of concrete as a result of adding composition of the additive. In this article, a modified additive (CMA) developed by the authors of the article is used as an additive were used post-alcohol bard-PAB (waste product of ethanol), sodium compounds (NaOH), and curing accelerant (gypsum) in different percentage ratios. To evaluate strength changes, samples have been made and were tested with compression and bending at 3, 7, 14, 21 and 28 days of the normally-moist curing. An experiment result demonstrated by adding an additive – plasticizer (PAB) has reduced the quantity of water to 35%, improving concrete strength up to 20%. Research reveals of the additives impact on the characteristics of the concrete during its manufacture. Consequently, adding additive (CMA) to the composition for concrete allows enlargement the strength after 28 days of curing up to 4.5-39% relative to the reference sample (Type 1). In accordance with the research results of the additive intensifies curing and was found to contribute to the enlarge of strength, both in early period, and at 28 days (design age). Experimental results revealed that the application of plasticizers is expedient from perspective quality improvement parameters of the compositions. Plasticizer in concrete mix significantly improves the resistance and durability of concrete. Consequently, the application of a modified additive enables to purposefully change the structure of heavy concrete and thereby significantly enlarge the complex of mechanical and physical parameters of modified heavy concretes.*

Keywords: *heavy concrete, compressive strength, bending strength, complex modified additive, plasticizer, post-alcohol bard, hardening accelerator.*

Аңдатпа. *Мақалада кешенді модификацияланған қоспаның (КМҚ) әсері, атап айтқанда қоспа компоненттерінің ауыспалы құрамының бетонның беріктік сипаттамаларына әсері туралы зертханалық зерттеулер келтірілген. Жұмыс ҚМҚ құрамына қосу арқылы бетонның пайдалану қасиеттерін жақсарту мәселесін шешуге арналған. Бұл жұмыста мақала авторлары әзірлеген кешенді модификацияланған қоспа (КМҚ) қолданылды, спирттік кейінгі барда (спирт өндірісінің*

қалдықтары), натрий қосылыстары (NaOH) және қатаю үдеткіші (гипс) әр түрлі пайыздық қатынаста пайдаланылды. Беріктіктің өзгеруін бағалау үшін 3, 7, 14, 21 және 28 күннен кейін қалыпты ылғалды қатаюдан қысу және иілу сыналған үлгілер жасалды. Эксперименттердің нәтижелері көрсеткендей, қоспаны – пластификаторды (алкогольден кейінгі тынығуды) қосқанда судың мөлшері 35 %-ға дейін төмендеп, бетонның беріктігін 20 %-ға дейін арттырды. Зерттеулер қоспалардың бетонды өндіру кезінде оның сипаттамаларына әсерін көрсетеді. Демек, ауыр бетонның құрамына қоспаны (КМҚ) қосу 28 күндік қатаюдан кейін беріктікті 1 типке (бақылау үлгісі) қатысты 4,5-39 % дейін арттыруға мүмкіндік береді. Зерттеу нәтижелері бойынша қоспа ерте кезеңде де, жобалық жаста да (28 күн) қатаюды күшейтеді және беріктігін арттыруға көмектеседі. Эксперименттердің нәтижелері үлгілердің сапалық көрсеткіштерін жақсарту тұрғысынан пластификаторларды қолдану орынды екенін көрсетті. Бетон қоспасындағы пластификатор ауыр бетонның беріктігі мен төзімділігін айтарлықтай арттырады. Демек, кешенді модификацияланған қоспаны қолдану бетонның құрылымын мақсатты түрде өзгертуге және сол арқылы модификацияланған бетондардың физикалық-механикалық сипаттамаларының кешенін едәуір арттыруға мүмкіндік береді.

Түйін сөздер: *ауыр бетон, иілу беріктігі, сығылу беріктігі, кешенді модификацияланған қоспа, пластификатор, спирттік кейінгі барда, қатаю үдеткіші.*

Аннотация. *В статье представлены лабораторные исследования влияния комплексной модифицированной добавки (КМД), а именно влияния переменного состава компонентов добавки на прочностные характеристики бетона. Работа посвящена решению проблемы улучшения эксплуатационных свойств бетона путем добавления в состав КМД. В данной работе использовали комплексную модифицированную добавку (КМД), разработанная авторами статьи, в качестве добавки были использованы послеспиртовая барда (отход производства спирта), соединения натрия (NaOH) и ускоритель твердения (гипс) в разных процентных соотношениях. Для оценки изменения прочности были изготовлены образцы, которые были испытаны на сжатие и изгиб через 3, 7, 14, 21 и 28 дней нормально-влажного твердения. Результаты эксперимента показали, что при добавлении добавки – пластификатора (послеспиртовая барда) произошло снижение количества воды до 35 %, что повысило прочность бетона до 20%. Исследования показывают влияние добавок на характеристики бетона в процессе его производства. Следовательно, добавление добавки (КМД) в состав тяжелого бетона позволяет увеличить прочность после 28 дней твердения до 4,5-39 % относительно Типа 1 (контрольный образец). Согласно результатам исследования, добавка интенсифицирует твердение и способствует повышению прочности, как в ранний период, так и в проектном возрасте (28 дней). Результаты экспериментов показали, что использование пластификаторов целесообразно с точки зрения улучшения качественных показателей образцов. Пластификатор в бетонной смеси значительно повышают стойкость и долговечность тяжелого бетона. Следовательно, использование комплексной модифицированной добавки позволяет целенаправленно изменить структуру бетона и тем самым значительно повысить комплекс физико-механических характеристик модифицированных бетонов.*

Ключевые слова: *тяжелый бетон, прочность при сжатии, прочность при изгибе, комплексная модифицированная добавка, пластификатор, послеспиртовая барда, ускоритель твердения.*

Inroduction. Most of the transformation of concrete as a building material does not occur in the development of new materials, but in the use of additives to improve its physical and mechanical properties. An additive can be selected, for example, depending on the technological application of concrete or to improve certain concrete properties: setting or hardening rate, increased strength, water absorption, frost resistance, etc. Among the most common chemical additives are plasticizers and superplasticizers that significantly reduce the water content of the concrete mixture. The use of plasticizers is a promising direction in increasing the efficiency of concrete and improving its performance properties.

Currently there are many different modified additives to improve the quality of concrete such as: C-3 and many others. The proposed additive has no analogues and is different in its quantitative composition of components. In this article, a modified additive (complex modified additive) developed by the authors of the article is used as an additive were used post-alcohol

bard-PAB (waste product of ethanol), sodium compounds (NaOH), and curing accelerant (gypsum) in different percentage ratios.

The choice of the additive was determined based on the main mechanism of their action. The advantage of CMA is that they are multifunctional. This means that they are able to influence several characteristics of the concrete mixture at once. Earlier studies confirm the peculiarities of each component, and in a complex synergistic effect is achieved [1-5]. Post-alcohol bard is a valuable product that can be used in solving the problems of environmental pollution and obtaining cheap raw materials. The main advantages of the additive were: water-reducing and plasticizing effect. Based on the above, it is necessary to evaluate the effectiveness of the developed complex modified additive (CMA).

The aim of the research is to obtain an additive that was not inferior in its functional properties to modern products and was obtained from local materials, exactly waste production. The present research included a complex laboratory experiment to assess the physical and mechanical properties of experimental samples, and a subsequent relative analysis of the change in the quality characteristics of the cement and the influence of a complex modifier was carried out. Nevertheless, within the framework of this article the results of the research will be presented, in particular, the influence of the variable composition of CMA on the strength characteristics of concrete.

Literature Review. Over the past few years, many researchers have obtained and published data showing that the combination of additives with cement provides a synergistic effect in concrete, allowing obtaining the best results contributing to improve the physical and mechanical properties [6-9]. Production of high-strength concretes is one of the modern trends in modifying the structure of building composites with additives of different composition and morphology [10]. The additive can be selected, for example, depending on the technological application of concrete or to improve certain concrete properties: setting or hardening speed, increased strength, etc. Among the most common chemical additives are plasticizers and superplasticizers, which significantly reduce the water content of the concrete mixture [11-14]. The use of such additives allows by reducing the water-cement ratio while maintaining a given fluidity of the mixture significantly increase the strength and durability of products. In addition, the introduction of plasticizers can affect the setting time and hardening kinetics of cement, increase strength, frost resistance and water resistance of concrete by reducing water consumption, as well as reduce cement consumption and energy consumption for the production of concrete, mortars, etc. [15].

In recent years, in connection with the development of complex modifiers on the basis of industrial wastes of polyfunctional action, the prospects of obtaining concrete with increased physical and mechanical characteristics have opened up. The obtained test results indicate the qualitative effect of the proposed complex organomineral modifier on the properties of concrete. [16-19]. Experience in the preparation of effective complex polyfunctional modifiers is described in the works of V.G. Batrakov, M.I. Higerovich, V.I. Soloviev, D.O. Baydzhanov, E.V. Tkach, S.M. Sharipov. The use of complex additives is now generally recognized as an effective way to improve the properties of cement concrete. In most cases, additives are now a mandatory component of the concrete mixture. Analysis of the scientific literature shows that additives that increase the rate of setting and hardening of cement are in demand, so the interest in developing new, competitively capable accelerating additives is not diminishing [20-22]. The development of modified heavy concretes for the general construction industry with improved technological parameters through the use of effective modifying additives is therefore relevant.

Materials and methods of research.

Cement. To conduct experimental work as a binder used Portland cement LLP «Kokshe-Cement» CEM I 42.5 N without addition, normal hardening.

Fine and Coarse Aggregates. Coarse aggregates – crushed stone (i.e. 10 mm) and sand quarry Akmola region. Gradation test carried out on the aggregates has shown they meet the specifications of Interstate Standard GOST.

In this article, a complex modified additive (CMA) developed by the authors of the article is used as an additive. As an additive were used: - modified additive - post-alcohol bard («main component» of the additive) is a waste product of ethanol, meeting the requirements of Technical Specifications 1110 RK 00393896 OJSC -01-2003, in quantities - 2.5%, 5.0%, 7.5%, 10% by weight of cement, the multiplicity is 2.5%. Supplied in liquid form, pH=5 (acidic medium), producer – JSC «Aydabul distillery»; - NaOH was used in small quantities, enough to obtain a neutral medium, i.e. for stabilization of pH of post-alcohol bard, in quantities of 5% (from post-alcohol bard); - hardening accelerant – gypsum, accelerating hardening process, in quantities – 1%, 1.5%, 2.0%, 2.5% from cement mass, pH=6 (slightly acidic medium), producer - JSC «Zhambylgips» Taraz gypsum factory.

The experimental research methodology includes the following steps: 1) Evaluation of the influence of CMA on the compressive strength of cement stone. Compressive and bending strength (40x40x160 mm) was determined in accordance with Interstate Standard GOST 30744-2001 «Cements. Methods of testing with using polyfraction standart sand» 6 samples were cast for each type and tested at the age of 3, 7, 14, 21 and 28 days using the Press Automatic Pilot equipment, with a compressive load of 500 kN, are shown in Figure 1; 2) Evaluation of the compressive strength (100x100x100 mm) of concrete samples was determined in accordance with Interstate Standard GOST 10180-2012 «Concretes. Methods for strength determination using reference specimens», 6 samples were cast for each type and tested at the age of 3, 7, 14, 21 and 28 days using the Press Automatic Pilot equipment, with a compressive load of 500 kN, are shown in Figure 1. After 24 hours the samples were de-molded, held in water and tested at the desired age. Weighing of components for the selection of compositions by mass was carried out on high-precision analytical scales. Water cement ratio was selected experimentally.

Figure 1. Bending and compressive strength tests

Results and discussion.

Bending and compressive strength tests**.** Research object was used cement-sand mixture at constant w/c ratio = 0.4 on the basis of ordinary cement «Kokshe-Cement» and with the use of polyfraction standart sand packed by 1350 grams. The strength test results of the reference sample of Type-1 (without additive composition) and with additive (CMA), during hardening period 7, 14 and 28 days are shown in Figure 2.

Analysis results of the executed experiments revealed that at Types 2-1 - 5-4 compressive strength limit at compression was within 42.8-63.6 MPa (28 days), while for reference sample Type 1 is 40.8 MPa, it means that this index in 1,5 times more than at the sample of Type 1. The hardening procedure appears to occur in the initial steps, and also keeps gaining strength evenly

in succeeding time and consequently enhances mark by strength, characterizing positively samples with the use of the additive (CMA). Probably, such differences in the influence on the cement stone when using the additive are due to different mechanisms of their action. While comparing to the strength index value of sample made according to sample being equal about 40.8 MPa with suggested compositions, being between 42.8-63.6 MPa, consequently assumed that sample Types 2-1 – 5-4 were of better quality. The greatest strength occurs is observed while applying the quantity of the addition additive in an amount equal to 2.5-7.5% of the mass of cement. That distinction was explained by the modified action of the additive on the dispersion and morphological composition of the new compositions of the cement stone. This is where the modified structure has greater resistance to fracture.

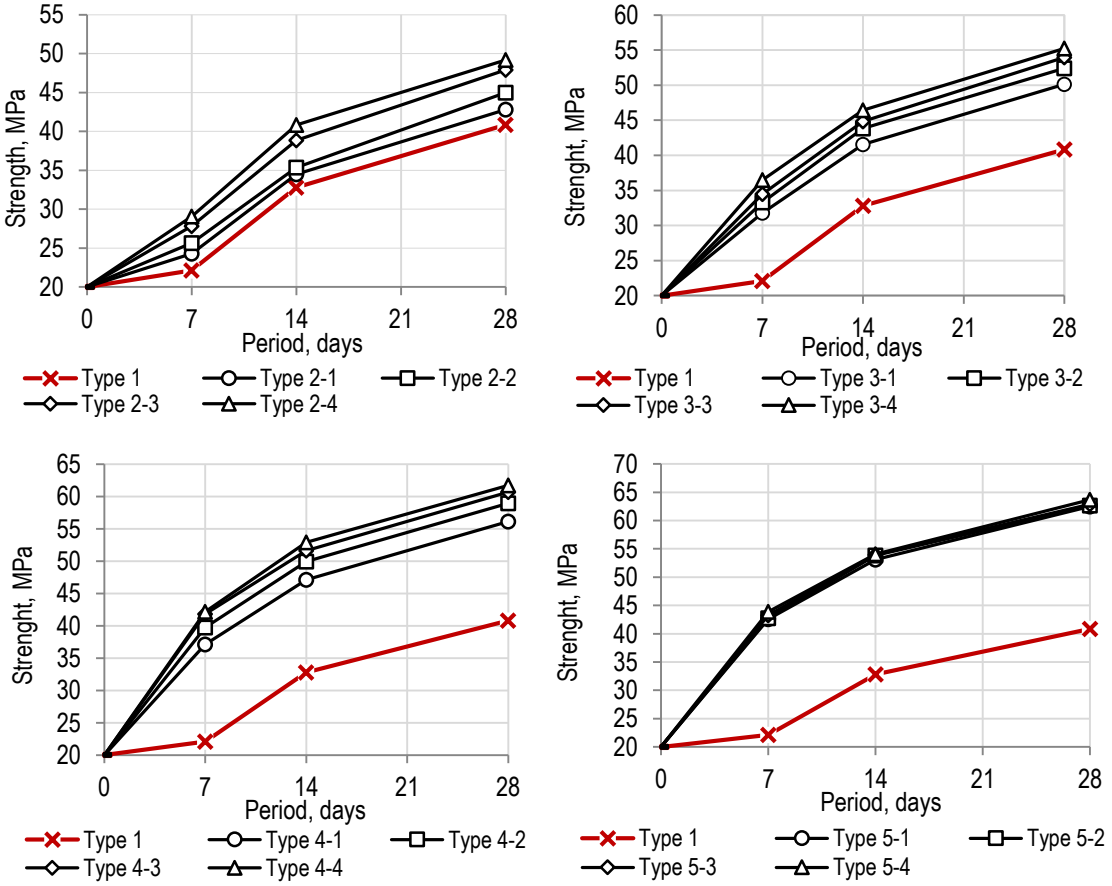

Figure 2. Graphs of compressive strength growth of tested samples

As a result of the data obtained it is possible to say that the samples with additive (CMA) has a greater strength for 7 days – 24.3-43.8%; for 14 days -34.5-54% and for 28 days – 42.8-63.6% while compared to the reference sample Type 1. In addition, the results stated that CMA improves rates of strength gains during the initial periods of curing and promotes great strength. Researches revealed that the compositions comprising 2.5 to 7.5% of additives have the highest effective, enabling for an average of 20% higher strength of the concrete. Mark by compressive strength of these samples exceeds the strength of unadded stone by 26.63%. Analysis of the results obtained shows a positive influence to the kinetics of curing with CMA on 7, 14 and 28 days, compared

with the original. The data results state that additive increases rate of strength gains and contribute to greater strength.

The diagram of the bending strength variation of samples depending on curing time is shown in Figure 3. The diagram analysis demonstrates sample strength growth gradually and evenly. The tests of the samples conducted with additive increase the strength up to 15-20%.

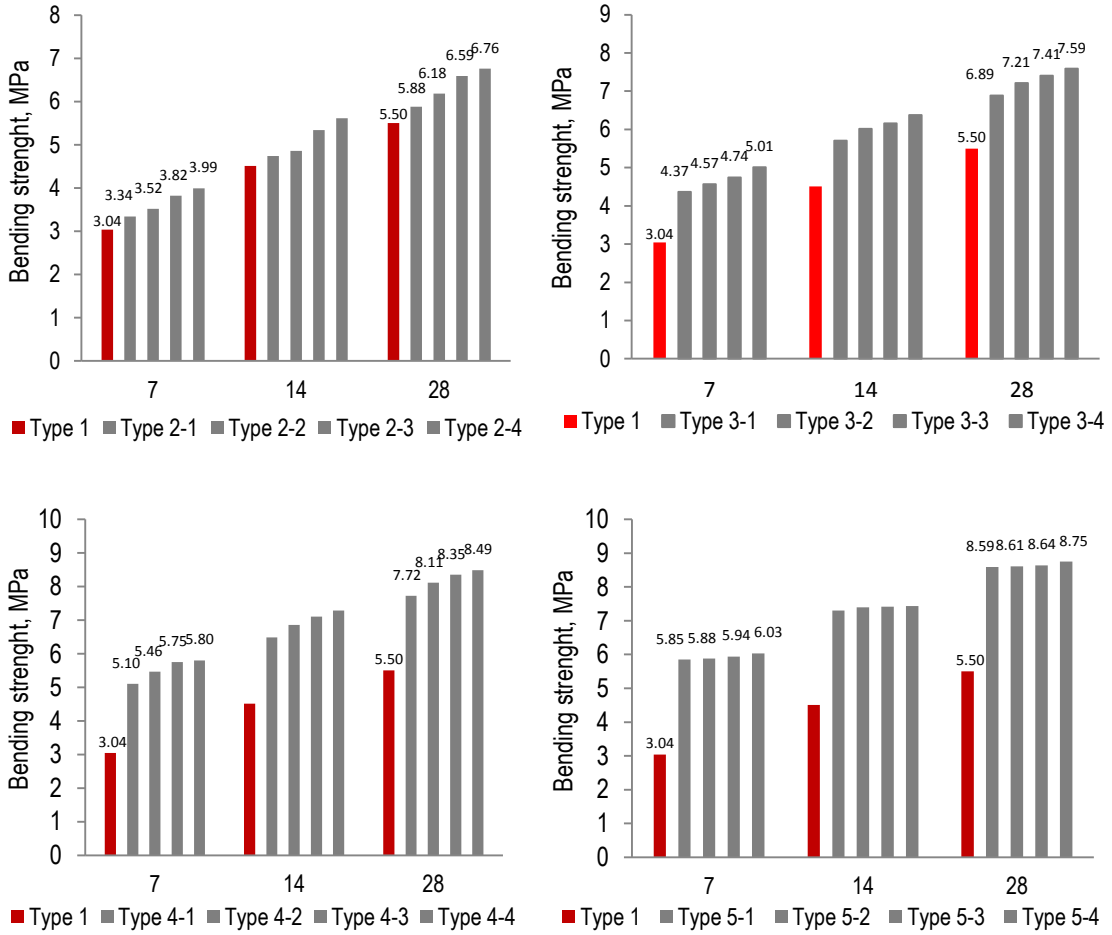

Figure 3. Bending strength of samples tested after 7, 14 and 28 days

High strength parameters were obtained in compositions ranging Types 3-1 to 5-4 with the content of the additive in an amount from 2.5 to 7.5% of the cement mass. The greatest bending strength was obtained for the composition Type 5-4 at 28 days of age, achieving 8.7 MPa (Figure 5). Insignificant increase in the bending strength observed when testing the beam samples obtained from compositions Types 5-3 and 5-4. The statistical evaluation of bending strength parameters also revealed a tight connection and relative high correlation between individual indicators. The variation coefficient in this case is no greater than 14%, and reliability indexes do not exceed 1.1 at 95% confidence probability. As the dose of additive increased, there was a quality change in the influence on strength and an intense increase in strength. Samples with different proportions of CMA (or without additive), illustrated clearly the benefit of a particular dose of CMA on strength, Figures 2 and 3. The additives have a significant influence of bending strength characteristics of samples in the process of hardening, establishing a stable frame in the structure, which is explained in the

consequent maximal growth of the indicators. These tests confirm the peculiarities of each component, and the synergistic effect is achieved in combination. Therefore, according to the tests carried out, it was established that the addition of additive to the cement composition, strength of samples tested for compression and bending, is improved.

Compressive strength test**.** The determination of concrete strength is the important parameter of heavy concrete after the additive has been added. 6 concrete samples of different types were tested at the age of 3, 7, 14, 21 and 28 days. The test results are shown in Figure 4. These results can be used to give a comparison of concrete samples obtained with additive and reference compositions.

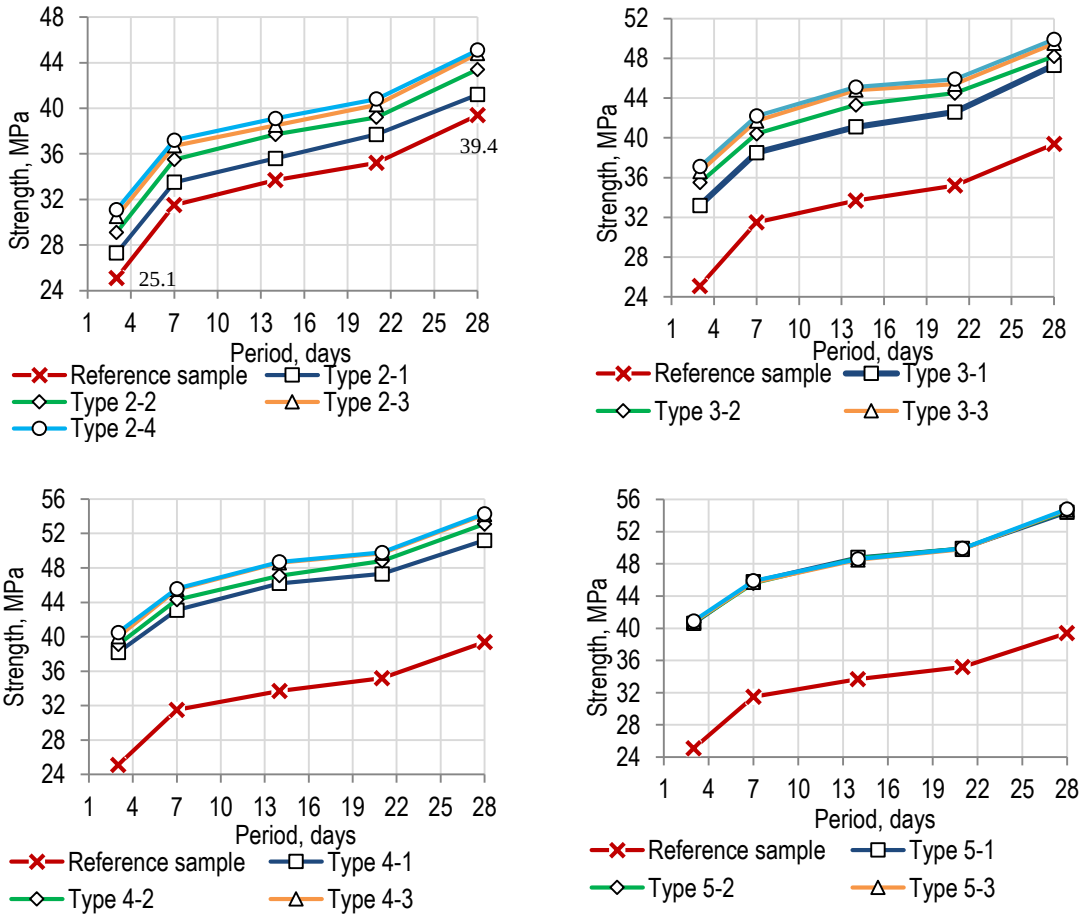

Figure 4. Cube compressive strength of concrete samples

In accordance with Figure 6 it can be seen exactly how setting strength to heavy concrete occurs using additive, which is one the primary characteristics of this kind of additive, improved mechanical and physical parameters. The strength with additive content increased in comparison with the reference sample with no modifier was observed on 3 days-8.7-62.9%, 7 days-6.3-45.7%, 14 days-5.6-44.2%, 21 days-7.1-44.7% and on 28 days-4.5-39%. The values of concrete strength of the additive (post-alcohol bard) 2.5-7.5% (in terms to dry substance) vary from one another, respectively, a necessary dosage should always be found, because lack and excess does not produce desirable effects. Advantages of the additive appeared the best if used at 2.5-7.5% of the

cement mass, which resulted in fast gain the strength in the early days and at 28 days the percent gain consisted of 4.5-39% more compared with Type 1- reference sample.

The analysis of results of experiments has shown, that in Types 2-1 - 5-4 compressive strength makes 41.2-54.8 MPa (28 days), and for the reference sample (Type 1) is 39.4 MPa, i.e. this parameter makes 1.5 times greater. The use of additive (CMA) gives the concrete strength higher as compared to reference sample during all hardening periods, accordingly the developed additive (CMA) the effective accelerator the hydration and curing according to Interstate Standard GOST 25192-2012 «Concretes. Classification and general technical requirements». Comparing the strength index of the sample preparation which is equal of 39.4 MPa with the suggested compounds, that ranged between 41.2-54.8 MPa, was possible claim that sample Types 2-1 - 5-4 were of better qualities. To achieve a fast strength gain, such feature of the additive as the impact on binder hydration helps. Application of the additive (CMA) enables achieving high workable plastified compounds by using additive (post-alcohol bard) in the quantity of 2.5-7.5% not lowering strength during specified duration of normal curing. Subsequent increase of the additive dosage reduces the design strength and a delay in the kinetics of strength growth. The addition of one of the components of the additive (post-alcoholic bard) into the concrete mix reduced the water content consumption of 8.75-35%, as well as reduced cement use of 1-2.5% while adding gypsum.

Conclusions. Based on experimental studies, the following conclusions can be drawn that the additive has a water-reducing and plasticizing influence. Analysis results of the executed experiments revealed that at Types 2-1 - 5-4 compressive strength limit at compression was within 42.8-63.6 MPa (28 days), while for reference sample Type 1 is 40.8 MPa, it means that this index in 1,5 times more than at the sample of Type 1. The greatest bending strength was obtained for the composition Type 5-4 at 28 days of age, achieving 8.7 MPa.

Analyzing the dependencies obtained, we can conclude that for this type of additive the maximum effect is observed at a concentration of 2.5-7.5% (post-alcoholic bard). Thus, the experiments conducted have shown that when mixing cement paste with additive there is a plasticizing effect on the mixture and a significant increase in the strength of concrete. This is of practical interest, since the addition of additives will accelerate the process of making products. Consequently, the use of a complex modified additive makes it possible to purposefully change the structure of concrete and thereby significantly increase the complex of physical and mechanical properties and durability of modified concretes.

References

1. Altynbekova, A., Lukpanov, R., Yenkebayev, S., Tsygulyov, D., and Nurbayeva, M. (2022). Complex laboratory studies of modified additive influence on concrete physical and mechanical properties. GEOMATE Journal, 23(100), 26–33. https://doi.org/10.21660/2022.100.3641
2. Altynbekova, A., Lukpanov, R., Dyussembinov, D., Askerbekova, A., and Tkach, E. (2022). Effect of a complex modified additive on the setting time of the cement mixture. Kompleksnoe Ispolzovanie Mineralnogo Syra, *325*(2), 29-38. https://doi.org/10.31643/2023/6445.15
3. Lukpanov, R., Dyussembinov, D., Altynbekova, A., and Zhantlesova, Z. (2022). Research of foam concrete components in the regional production conditions of Nur-Sultan. Technobius, *2*(3), 0023. https://doi.org/10.54355/tbus/2.3.2022.0023
4. Lukpanov, R., Dyussembinov, D., Altynbekova, A., and Zhantlesova, Z. (2022). Research on the effect of microsilica on the properties of the cement-sand mixture. Technobius, *2*(4), 0027. https://doi.org/10.54355/tbus/2.4.2022.0027
5. Altynbekova A.D., Lukpanov R.E., Yenkebayev S.B., Dyussembinov D.S., Yerzhanova N.K. Fast-hardening workable concrete for the production of bored. Building and Reconstruction. 2022;(2):99-111. (In Russ.) https://doi.org/10.33979/2073-7416-2022-100-2-99-111
6. N.Z. Muhammad, A. Keyvanfar, M.Z. Abd. Majid, A. Shafaghat, J. Mirza, Waterproof performance of

concrete: A critical review on implemented approaches, Construction and Building Material, 101, 2015, pp. 80–90, https://doi.org/10.1016/j.conbuildmat.2015.10.048
7. S. Marceau, F. Lespinasse, J. Bellanger, C. Mallet, Microstructure and mechanical properties of polymer-modified mortars, European Journal of Environmental and Civil Engineering, 16, 2012, pp. 571–581, https://doi.org/10.1080/19648189.2012.675148
8. C. Qingyu, S. Wei, G. Liping, Z. Guorong, Polymer-modified concrete with improved flexural toughness and mechanism analysis, Journal of Wuhan University of Technology-Materials Science Edition, 27, 2012, pp. 597–601, https://doi.org/10.1007/s11595-012-0512-5
9. J. Plank, E. Sakai, C.W. Miao, C. Yu, J.X. Hong, Chemical admixtures-Chemistry, applications and their impact on concrete microstructure and durability, Cement and Concrete Research, 78, 2015, pp. 81–99. https://doi.org/10.1016/j.cemconres.2015.05.016
10. Poluektova V.A., Kosukhin M.M., Malinovker V.M., Shapovalov N.A., Multifunctional superplasticiser for concrete on the basis of pyrocatechin production wastes, Fundamental research, 1(3), 2013, pp. 718-722.
11. F. Jingjing, L. Shuhua, W. Zhigang, Effects of ultrafine fly ash on the properties of high-strength concrete, Journal of Thermal Analysis and Calorimetry, 121, 2015, pp. 1213–1223. https://doi.org/10.1007/s10973-015-4567-3
12. Shamshygaiyn T., Talgat Akhmetzhanov, G.B., Tanirbergenova A., Yeleussinova A., Effect of complex additive on exothermic kinetics and hydration stages of cement systems, GEOMATE Journal, Vol. 19(75), 2020, pp. 184–190. https://doi.org/10.21660/2020.75.95831
13. Kolesnikov A, Fediuk R, Kolesnikova O, Zhanikulov N, Zhakipbayev B, Kuraev R, Akhmetova E, Shal A. Processing of Waste from Enrichment with the Production of Cement Clinker and the Extraction of Zinc. Materials. 2022; 15(1):324, pp.1-9. https://doi.org/10.3390/ma15010324
14. Kolesnikov A.S. Zhakipbaev B.Ye, Zhanikulov N.N., Kolesnikova O.G., Akhmetova E.K., Kuraev R.M., Shal A.L. Review of technogenic waste and methods of its processing for the purpose of complex utilization of tailings from the enrichment of non-ferrous metal ores as a component of the raw material mixture in the production of cement clinker. Rasayan Journal of Chemistry, 14 (2), 2021, 997-1005. doi: http://dx.doi.org/10.31788/RJC.2021.1426229
15. Pan X, Xiao Y, Suhail SA, Ahmad W, Murali G, Salmi A, Mohamed A. Use of Artificial Intelligence Methods for Predicting the Strength of Recycled Aggregate Concrete and the Influence of Raw Ingredients. *Materials*. 2022; 15(12):4194. https://doi.org/10.3390/ma15124194
16. Baydzhanov D.O., Khan M.A., Sadirbaeva A.M., Ikisheva A.O., Divak L.A. The effect of the complex additive on the timing of the setting of the cement paste and the structure of the cement stone. International Journal of Applied and Basic Research, 2018, 2, pp. 17-22.
17. K.A. Abdrakhmanova, D.O. Baydzhanov. Influence of complex mineral additives and plasticizer on the properties of cement stone. Mechanics & Technologies. 2019, 3, pp. 92-96.
18. Bajdzhanov D.O., Zhumagulova A.A., Divak L.A., Dileev I.M., Sherstov A.I. Influence of complex modifier – ecap, to foam concrete properties. Fundamental research. 2013, 8 (11), pp. 1567-1570.
19. Tkach E.V., Rakhimova G.M., Seidinova G.A., Ikisheva A.O., Dadieva M.K. Effect of organic modifiers on density and normal setting times of cement. Technical sciences. 2012, 11, pp. 1220-1223.
20. Swaminathan P, Karthikeyan K, Subbaram SR, Sudharsan JS, Abid SR, Murali G, Vatin NI. Experimental and Statistical Investigation to Evaluate Impact Strength Variability and Reliability of Preplaced Aggregate Concrete Containing Crumped Rubber and Fibres. Materials. 2022; 15(15):5156. https://doi.org/10.3390/ma15155156
21. Prithiviraj C, Swaminathan P, Kumar DR, Murali G, Vatin NI. Fresh and Hardened Properties of Self-Compacting Concrete Comprising a Copper Slag. Buildings. 2022; 12(7):965. https://doi.org/10.3390/buildings12070965
22. Ramachandran K, Vijayan P, Murali G, Vatin NI. A Review on Principles, Theories and Materials for Self Sensing Concrete for Structural Applications. Materials. 2022; 15(11):3831. https://doi.org/10.3390/ma15113831