ABSTRACT

M. T. Kuttybai's dissertation work is submitted for obtaining the degree of Doctor of Philosophy PhD in the educational program 8D07340 - "production of building materials, products and structures"

The topic of the dissertation is "Improving the operational properties of cast modified concrete based on ferroalloy production waste"

Relevance of the research topic. In the construction industry, high performance requirements are imposed on cast modified concretes, covering a wide range of performance characteristics, among which special attention is paid to strength characteristics, the ability of the material to resist moisture, resistance to repeated freezing and thawing, and the ability to maintain integrity when interacting with aggressive substances [1]. Numerous studies have demonstrated the possibility of strengthening building structures by using polymer additives with high chemical resistance [2]. However, due to the high cost of production, polymer concretes have not been widely used, as a result of which traditional concrete mixes are still the main structural material in construction. In European countries, the development and implementation of structures made of monolithic modified concrete has reached a significant level: there is both extensive experimental data and successfully operating production technologies. In the territory of the Republic of Kazakhstan, this area is still at the stage of scientific research and local production tests, having not received widespread industrial use [3]. Based on this, the task of developing cast modified concretes with increased resistance to aggressive environments by purposefully changing their internal structure seems relevant and practically significant.

To achieve this goal, the key task is to create a high-density cast modified concrete structure that provides a balanced combination of technological performance and operational reliability. This is achieved through the use of dispersed-differentiated binding components that promote dense packing of particles in each local micro-volume of the material, combined with the use of complex multicomponent modifiers [4-5].

The study was conducted within the framework of the State Program of Industrial and Innovative Development of the Republic of Kazakhstan for 2020-2025.

The degree of development of the topic. An analysis of the scientific works of domestic and foreign researchers, as well as current regulatory and technical documents, revealed a steady interest in the problems of increasing the durability of concrete materials, especially in conditions of aggressive external influences. Therefore, special attention is paid to strategies for increasing

sustainability by optimizing the composition and structure of cement systems. Despite a significant amount of research in the related field, the topic of forming cast modified concretes using polyfraction cement systems in which strictly controlled granulometry is carried out, as well as using a composite modifier consisting of three components (including a superplasticizing agent, a polymer component and microsilicon) remains scientifically insufficiently developed. This is especially evident in the context of studying how this modification affects the patterns of structural self-organization of the cement matrix, as well as the final consumer and physico-chemical parameters of the hardened composite material.

A scientific hypothesis. Most likely, the key to the formation of cast modified concrete with high strength, resistance to cracks, frost, moisture and aggressive influences is a detailed control of the fractional composition of the cement component in combination with the action of a three-component modifier. It is assumed that such an engineering compound initiates the formation of a spatially ordered microstructure with pronounced crystallinity and dense packing of elements, thereby achieving high structural stability and long-term operational reliability of the composite. The presence of microsilicon in the system enhances the development of the secondary Pozzolan reaction, which results in the formation of chemically resistant low-pressure calcium hydrosilicates of the CSH(B) type. This, in turn, provides a further increase in the corrosion resistance of the material when working in aggressive conditions.

The purpose and objectives of the study. The dissertation is devoted to the creation of a scientifically sound and technologically feasible approach that makes it possible to obtain cast concrete with a modified structure that can function effectively in aggressive operating conditions. A key component of this approach is the introduction of a polyfraction binder with controlled grain distribution, which includes a three—component modifier - a combination of hyperplasticizer, polymer additive and silica. It is assumed that such a complex should provide the necessary performance indicators and operational reliability of the finished material.

To accomplish this task, it is planned to consider the following research areas in stages::

- determination of the most optimal composition of the cement binder, which makes it possible to achieve maximum substrate density at the micro level;

- obtaining a cast concrete system with a purposefully modified structure combining a polyfractional viscous base and a three-component modifier, and then evaluating the effect of such a composition on the technological parameters of the mixture;

- a detailed study of the effect of the complex modification composition and the cumulative effect of the binder, distributed by fractions, on the structural evolution of cement stone and the final physical and mechanical parameters of the laid concrete;

- development of an applied algorithm for adapting the obtained concrete material to mass production conditions, followed by its targeted use in the construction of structural elements operating in aggressive environments, including mandatory technical verification of its effectiveness and analysis of operational reliability at the engineering level.

The object of the study is a type of cast concrete with specified modifying characteristics, characterized by a polyfractive structure and obtained on the basis of a cement binder with the addition of three functional additives – superplasticizer, polymer component and silica. The main purpose of the material is related to its use in construction projects carried out in conditions of intensive operation.

The subject of the study is a number of parameters that determine both the internal organization of the structure and the operational properties of modified cast concrete. The polyfraction bonding system studies the effect of a combination of finely dispersed components and modifiers on the properties of concrete, paying special attention to concrete strength, moisture, frost resistance and resistance to aggressive media due to the high density of the shell.

Scientific novelty. A scientifically proven method for producing cast modified concrete has been developed based on the use of a polyfractional cement binder with controlled granulometry, which contributes to the formation of a dense spatially ordered structure of cement stone.

The effect of a three-component modifier (superplasticizer AP-122, polyvinylpyrrolidone, microsilicon MK-95) on the intensification of hydration processes and the formation of stable calcium hydrosilicates of the CSH(B) type, providing increased strength and performance characteristics of the material, has been established.

For the first time, the formation of a uniform microcrystalline structure of a cement conglomerate with a pore system with a diameter of 0.1–0.5 microns has been experimentally confirmed, which reduces water absorption to 2.1% and increases the frost resistance of concrete to F600.

A new composition of cast modified concrete has been proposed, providing compressive strength up to 66.1 MPa and water resistance up to the W12 level, which confirms its effectiveness for use in aggressive environments.

A regulatory technical document (TR "LMB2022") regulating the use of modified cast concrete in industrial construction has been developed and implemented.

The theoretical and practical significance of the work. Based on the conducted research, new information has been obtained on the mechanism of structure formation of concretes obtained using polyfraction binders and complex triple mixtures (containing superplasticizers, water-soluble polymers and amorphous silica) with a controlled granulometric composition. It has been established that the creation of a microcrystalline structure in a cement matrix and maximizing the packing density of the solid phase improve the physico-mechanical properties of cast modified concrete.

The material developed in the framework of this study is the result of purposeful adaptation of cast modified concrete to operating conditions in highly aggressive environments. The composition presented in the work was created not only as a chemical and technological solution, but also as an engineering answer to the issues of sustainable development. The resulting mixture has a number of properties that ensure its suitability for use in difficult conditions.: The strength index reaches 66.1 MPa when compressed and 7.8 MPa when bent. The value of the strain intensity coefficient, which shows the ability of a material to resist crack growth, is 0.07467 MPa x m^0. At the same time, water absorption is reduced to a minimum — no more than 2.1%. The material successfully passes the water resistance class, reaching the W12 level, and frost resistance is confirmed at the F600 level. In addition, it is worth noting its resistance to the destructive effects of chemicals, which is important when used in infrastructure prone to corrosion.

Methodology and methods of dissertation research. For the dissertation research, an approach based on the integration of several scientific rules reflecting the principles of creating specific materials with specified operational parameters was chosen. The theoretical basis is the concept of system analysis in the field of materials science, which makes it possible to determine the relationship between the structural structure, the composition of components and the physical and mechanical properties of the final product. The complexity of experimental procedures is ensured by the use of proven scientific analysis tools. These include X-ray phase control methods, detailed microstructure scanning, chemical testing, and laser granulometry used in combination with mathematical data processing. This synthesis made it possible to effectively select the parameters of fine particles of the cement component, taking into account the shrinkage density of the particles and their geometric properties, which further determined the structural stability and strength of the resulting matrix.

Provisions to be defended:

- The scientific verification of the possibility of achieving high performance of cast concrete is based on the introduction of a special formulation of cement binder with an adjustable grain structure and maximum packing density, as well as the use of a mixture of polycarboxylate, polymer and silica as a single integrated modification system.

- The systemic results obtained as a result of a step-by-step study of the synergistic effect of the triple modifier focus on its effect on the stage of structure formation, micromorphology and final properties of cement stone and composite as a whole.

- The empirical determination of the dependence of critical strength characteristics, including compressive strength, bending strength, as well as light resistance, cyclic freezing and chemical destruction parameters, is directly related to the change in the composition of the modifying mixture in a multicomponent system based on a finely dispersed mineral binder.

- Conducting an analytical assessment of the technical and economic efficiency of the developed formulations of casting materials, and the parameters of their introduction into production are designed taking into account costs, resource efficiency and profitability.

The degree of reliability of the results. The central element of substantiating the reliability of the results is a set of factors that minimize the impact of random and non-permanent distortions. The main condition is the use of high-precision research and measuring instruments that work stably in many tests. The control methods used are based on proven measurement procedures that provide a confidence interval of at least 0.96. In addition, mathematical and statistical analysis methods were used to interpret the data obtained, which made it possible to identify regular dependencies and exclude statistically insignificant deviations. All this creates a solid foundation for reliable confirmation of the validity of the conducted research in the complex. Verification of the operability of technical solutions during experimental tests and conducting practical tests of concretes designed for use in harsh conditions have yielded good results.

Approbation of the work. The main content and conclusions of the dissertation research were verified at the scientific forum: II International Conference "Industrial Construction" (Almaty, 2025). III Scientific and Practical Conference "Features of design, construction and operation of buildings and structures with active seismic protection" (Almaty, Nao Runnit, 2024) International Scientific and practical Conference "Features of design, construction and operation of buildings and structures with active seismic protection" (Almaty, Nao Runnit, 2024) Practical Conference "Prospects modern production of energy-saving building materials" (Tashkent, 2023, Tashkent).

Implementation of the research results. The industrial introduction of the developed cast modified concrete was carried out at the Temirbeton-1 enterprise in the production of reinforced concrete products: 200 trays of the L9-11 series and 100 trays of irrigation systems of the LR-6 type were manufactured.

Personal contribution of the applicant. The candidate formulated the goals and objectives of his dissertation research, selected testing methods, and analyzed and interpreted the results. To ensure dense packaging of the fine fraction of clinker components, special attention was paid to the study of the grain composition of cement binders, which was implemented using software and computer systems using mathematical algorithms. The composition of the modified concrete mix has been optimized in order to improve its physical and technological properties. Recommendations for the use of concrete in harsh environments. Scientific publications have published on research topics.

Publications. The generalized rules of dissertation research are reflected in six scientific papers: Three are in international journals registered in the Scopus citation database.

1. Saduakasov M., Talal A., Kopzhasarov B., Akhmetov D., Nurumov R. (2025). Structural thermal insulating foam concrete properties for foundation insulation. International Journal of GEOMATE, Feb., 2025 Vol.28, Issue 126, pp.25-32ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2025.126.4545 (SCOPUS Q3)

2. Abdraimov I., Talal A., Kopzhassarov B., Kuttybay M., Akhmetov D., Tynybekov R. (2024). Strength and durability effect of self-compacting concrete reinforcement with micro-silica and volume fiber. International Journal of GEOMATE, July, 2024 Vol.27, Issue 119, pp.26-33 ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2024.119.4334 (SCOPUS Q3)

3. Begentayev M., Kuldeyev E., Akhmetov D., Zhumadilova Zh.,Suleyev D. (2025). The Effect of Mineral Fillers on the Rheological and Performance Properties of Self-Compacting Concretes in the Production of Reinforced J. Compos. Sci. 2025, 9(5), 235; https://doi.org/10.3390/jcs9050235(SCOPUS Q1)

Two of them have been published in peer-reviewed scientific journals included in the list approved by the Committee on Quality of Science and Higher Education of the Republic of Kazakhstan.

1. Kopzhassarov B., Akhmetov D., Zhagifarov A., Abdraimov I., Kuttybay M., Zhumadilova Z. (2024). Quality improvement effectiveness of road slabs produced using microsilica and fiber. QazBSQA Swag. Saulet zhane Kurylys. No.2 (92), Almaty 2024. B.76-90 https://doi.org/10.51488/1680-080X/2024.2-06 Received (KOKSNVO RK)

2. Kuldeyev E., Zhumadilova Zh. Zhagifarov A., Tolegenova A., Kuttybay M., Alikhan A. (2025). Physicochemical properties of silica fume and fly ash from Tau-Ken Temir LLP and Pavlodar CHP for potential use in self-compacting concrete. Technobius, 2025, 5(1), 0076, DOI: https://doi.org/10.54355/tbus/5.1.2025.0076 (KOKSNVO RK)

And the remaining one is a patent for a utility model.

1. Kuldeev E.I., Zhumadilova Zh.O., Akhmetov D.A., Kuttybai M.T. (No. 10360). Composition for the preparation of self-sealing concrete. [The patent].

The volume and structure of the dissertation. The volume of the dissertation is 183 pages, including the structural elements stipulated by the Academic Standard: a table of contents, an introductory part, a main report in five thematic chapters, a final conclusion, a bibliographic list containing 137 sources, and one appendix. The illustrative material is presented in the form of 41 tables and 25 graphic diagrams and figures.

Conclusions on chapter I

One of the most acute problems in Kazakhstan's water sector remains the deterioration of the infrastructure of land reclamation systems, in particular reservoirs, which are operating at the limit of their resources and have lost their lifting and hydraulic properties over the past two and a half decades. An analysis of the current situation shows the systemic need for reconstruction of every fourth element. This reality poses an acute engineering and scientific challenge — to create cast concrete with fundamentally different operational properties, capable of withstanding the aggressive loads inherent in hydraulic structures.

The main direction of this transformation is the design of the concrete microstructure not as a side effect of hardening, but as a controlled system with certain parameters. It is based on a polyfractional cement binder containing strictly selected fractions and a three-component modifying composition that interact synergistically with a superplasticizer, a functional polymer and highly active silica. This approach is aimed not at improving a single property, but at completely rebuilding the entire structure — from fluidity in a new state to density and corrosion resistance in a hardened state.

The key point is not only a decrease in the water-cement ratio, but also a sharp increase in the proportion of the solid phase as the particle packing approaches the maximum density limit. The formation of a multilevel grain architecture with the presence of residual large fractions makes it possible to create a long-term strength frame inside the array that compensates for operational stresses and works with the effect of internal self-healing.

In a cement matrix reinforced with microsilicon MK-95, there is a sharp reduction in capillary space, the elimination of weak transition zones, and the

formation of a chemically inert, spatially organized shell resistant to acids, salts, and heat transfer. It's not just about improving performance, it's about switching to a new class of concrete that is adapted to harsh water conditions and can maintain structural integrity for decades without losing strength or durability.

Conclusions on chapter II

The cast modified concrete with a triple additive system (hyperplasticizer, silica, polymer, polypropylene fiber) has been developed, which has high physical and mechanical characteristics: compressive strength — 67.1 MPa, bending strength — 7.28 MPa, water absorption — 2.1%, frost resistance — F600, water resistance — W12. The use of ferroalloy production waste has further increased the moisture resistance and durability of the material.

Optimization of the granulometric composition of the cement binder (with fraction size: 12 microns — 15%, 6.6 microns — 75%, 4.9 microns — 10%) and accurate selection of dosages of modifying additives (0.2% povidone-K30, 0.7% polypropylene fiber) provided increased strength while reducing cost.

Conclusions on chapter III

Based on the methodology of formulation of additives for concrete proposed by Professor Nakamura, the initial version of the formula of modified monolithic concrete was developed. During laboratory tests, experimental adjustment of the parameters of the mixture for concrete grade M30, corresponding to strength class B450, was carried out. As a result, the values of the rheological properties of the adjusted composition were also recorded.

During the preliminary analysis, the distribution of polyfraction systems was modeled, including three fractions of varying degrees of dispersion: F1 – average particle diameter d_sr = 12 microns, specific surface area S_sr = 1500 cm2/g; F2 – d_sr = 6.6 microns, S_sr = 3000 cm2/g; F3 – d_sr = 4.9 microns, S_sr = 4500 cm2/g. The results showed that the packing density of the particles varies from 0.555398 to 0.620393. The minimum packing value is fixed for the composition 100/0/0, the maximum for the composition 60/20/20. Composition No. 6, which includes 15% of the fraction 1500 cm2/g, 75% of the fraction 3000 cm2/g and 10% of the fraction 4500 cm2/g, is considered optimal in terms of the combination of technological and physico-mechanical parameters, while a stable positive correlation is observed between the packing density and the strength of concrete.

The regression equations of the second order (3.10, 3.11, 3.12) reliably show the relationship between changes in compressive strength, the conditional coefficient of strain intensity and water absorption of cast modified concrete with variable parameters: the mass content of polymer povidone-K30 (hakt) and the volume concentration of polypropylene fiber (x_2).

Using the mathematical toolkit Matlab R2022a, the extreme values of the objective functions of regression equations are determined. It was found that

MAX Y1 = 77.5 at x1 = 0.0235 and x2 = 0.0928 (in terms of 0.202% and 0.714 %, respectively);

MAX Y2 = 0.075 at x1 = 0.2667 and x2 = 0.2355 (calculated as 0.227% and 0.734%, respectively);

MIN Y3 = 2.352 at x1 = 0.390 and x2 = 0.130 (calculated as 0.238% and 0.718%, respectively).

Numerical analysis determines the optimal values of the variable factors: x1_opt = 0.2 and x2_opt = 0.7 in natural coordinates. These parameters make it possible to simultaneously achieve maximum compressive strength and reduce water absorption. Substituting the values found, the regression equations gave the following material properties: rsh = 77.4 MPa, coefficient of conditional strain stress Kc * = 0.074 MPa xM0.5, water absorption Wm = 1.9%.

Conclusions on chapter IV

The analysis of the phase composition presented in Table 4.2 showed that, unlike using standard cement (composition 1-Cem I 42.5 h), an increase in the proportion of clinical compounds is observed during the transition to polyrefractive adhesive (composition 2). This decrease is directly related to the presence of large, partially inert fractions (1,500 cm2/g) in it, which act as a reserve of clinker material. When replacing the polyfraction binder with hyperplasticizers AP122 (component 3) or Povidone-K30 (component 4), a slight loss of taps and c-c content was recorded, not exceeding 1-2% relative to the basic composition.2. With the simultaneous addition of both components (composition 5), a similar decrease in the proportion of clinker phases was observed, however, the hydration level increased to 57%, which indicates an increase in hydration processes. 15% microsilicon MK-95 -. (composition 6) With further administration, the pozzolan reaction intensified: the amount of portlandite Ca(OH)2 decreased by more than 2% compared to 26, and stable low-base calcium hydrosilicates began to predominate in the structure. The promising concept of using clinker raw materials was confirmed by the results of long-term tests: after 6 months in the 7th batch, the content of clinker and sulfates decreased by 10% and 11%, respectively, the amount of Ca(oh) decreased to 10.4%, and the degree of hydration increased to 82%. Thus, the introduction of a coarse-grained fraction (Sk = 1500 cm2/g) ensures the long-term development of the cement stone structure and contributes to the formation of high-strength concrete.

Electron microscopy of the cement stone revealed radical changes in its structure. The influence of hyperplasticizer, polymers and microsilicon led to the formation of a strong and homogeneous porous matrix, in which the accumulation

of needle-like crystals of ettringite is especially noticeable. The size of these crystals has decreased significantly, reaching 60-70 nm. The structure of cement stone is currently characterized by a massive fine-porous mesh with pore sizes from 0.1 to 0.5 microns, which in turn indicates the development of a high density of the material and potential resistance to aggressive external influences.

Comparative tests of the control cement system and modified formulation No. 6 revealed clear rheological advantages. A decrease in the completion time by 7 seconds was observed with the introduction of a polyrefractive adhesive containing an additive package (ar122 – 1.7%, povidone-K30 – 0.2%, MK-95 – 15%) and polypropylene fiber (0.7%).when the folding index decreases by 10%. It can be noted that the observed changes in the parameters directly affect the performance characteristics of the composite: thanks to modifying additives, it is possible to reduce fractional stratification, suppress the processes of coarse-grained filling, and even out the morphology of the concrete mass in vertical sections.

It has been established that the mechanical parameters of cement systems during compression and bending are clearly related to the use of modifying components. An analytical review allows you to create a report:

- Composition 5 (PV + ar122 1.7% + povidone-K30 0.2% + MK-95 15%) exceeded control sample 1 (PK + ar122 1.7%) by 14.4 MPa (+29%), and variant 2 (PV + ar122 1.7%) by 8.4 MPa (+15%), which confirms the synergistic effect of the complex modification;

- The addition of 60.7% polypropylene reinforcing fibers provided an increase in compressive strength from 4.7% to 5%, however, experimental data show that exceeding the critical limit of fiber concentration leads to a tendency for structural elements to stick together, followed by a decrease in mechanical properties;

- The test results revealed composition 6 (+ir modifier) as the leader in bending strength – the threshold values of r_tb exceeded the control by 1.78 MPa (+32.4%), and sample 5 – by 0.67 MPa (+10.1%), which indirectly indicates the role of fibers in stress redistribution during deformation.

The patterns of fracture and the parameters of crack formation in prisms made of LMB have been radically rethought. Key observation: Fiber reinforced samples (version 6) demonstrate a nonlinear fracture scenario — the initial crack zone gradually expands with an increase in stress by 35.2% during bending compared to the control. In the modified systems, the stress concentration index increased by 40.91%, which may be due to energy dissipation through their bridges. Interestingly, the kinetics of cracking in polypropylene compositions had quasi-plastic properties.: Instead of catastrophic decay, a multi-stage "swelling" of defects was observed. This phenomenon indirectly confirms the hypothesis of

attenuation of micro—deformations - reinforcing elements are able to absorb part of the destructive loads, transferring brittle chips into a controlled degradation process. It is worth noting the paradox: despite the improvement in light fastness, an excess of fibers (more than 0.7%) causes a feedback effect — the accumulation of fibers creates new stress concentrations.

The tests have confirmed the improvement of the hydrophysical characteristics of the modified compounds. In particular, composition 6 (PV + 1.7% AR122 + 0.2% Povidone-K30 + 15% MK-95 + 0.7% PF) demonstrated a 52.3% decrease in water absorption compared to the control sample (composition 1). Similar indicators for other studied formulations were: 34.1% (composition 2), 40.9% (composition 3), 45.5% (composition 4), 50% (composition 5).

The cryostability of concrete systems revealed unusual patterns when testing modified samples. Formulations 5-6 with multifunctional additives showed record breaking viscosity: after a temperature increase of 600 ° C, the mass loss did not exceed 1.7-1.8%, and the strength regression remained at the level of 9.3-10.1%. The observed phenomenon allows us to put forward the thesis of a synergistic effect: the combination of chemical plasticizers and fiber reinforcement can prevent capillary migration of moisture by changing the structure of the pore space. It is interesting to note the paradox – despite the uniformity of the indicators, the composition of 6 with fibers shows a slightly lower degradation in strength (9.3% versus 10.1%), which can be explained by the fact that microfraction acts as a stress distribution grid in the areas of ice lenses.

Experimental tests of the corrosion resistance of LMB systems revealed abnormal resistance of the modified samples. It can be said that composition 6 (PV + [ar122 1.7% + povidone-K30 0.2% + Mk-95 15%] + PF 0.7%) exhibits maximum inertia in relation to chemical aggression:

The rate of mass decomposition in the chloride medium (3% NaCl) decreased by 29.3%, and the regression of compressive/flexural strength was 38.8% and 30%, respectively, compared with the control group;

Acid exposure (0.01 m HCl) led to a decrease in performance - weight decreased by 27.7%, compressive strength by 27.4%, bending strength by 23.7%;

Tests of purified water simulating leaching revealed abnormal trends: mass loss during a catastrophic decrease in power decreased by 18.6% to 50.4% (compression) and 49.6% (bending) compared to the control background.;

The effect of sulfate (5% Navsoox) caused the opposite changes – the dynamics of mass growth slowed down by 24.3%, compressive strength increased by 20%, bending strength increased by 18.3% and showed an inverse relationship. The paradoxical effect may be due to the formation of protective phases in the matrix due to exposure to sulfate.

Conclusions on chapter V

Tabular data revealed the fundamental superiority of the innovative concrete matrix over the reference systems. Cascade modification based on a polyfraction binder combining ferroalloy residues, a polymer matrix (ar122 — 1.7%, povidone-K30 — 0.2%) and 0.7% polypropylene fiber allowed to reset the profile of the material's performance characteristics. The synergy of the components can be called a catalyst for improving quality: microsilica (15%) forms a dense matrix, fibers prevent cracking, and the polymer complex inhibits destructive processes.

The use of industrial waste has not only reduced, but also increased barrier properties, an effect that may be due to the formation of nanoscale intermetallic layers in the cement matrix.

In the production year, it is planned to consume 67,060 Gcal of thermal energy for the needs of heating and hot water supply, the calculation of the cost of these resources is fixed in the table.5.3. As for the consumption of cold water, its volume is determined taking into account the standards for technological operations and sanitary needs in accordance with the requirements of "SNiP 2.04.01-85*" SP 30.13330.2016, regulating the design of internal water supply and sewerage systems of buildings.

As a result of calculations, it was determined that the transition to a technology using a polyfraction binder in combination with a complex mixture containing hyperplasticizer AP122, polymer povidone-K30 and microsilicate MK-95 will save 2,462 tenge per cubic meter of modified concrete laid, based on the price level of 2024.

The technical effectiveness of the developed composition of cast modified concrete, including a polyfractional binder, waste from ferroalloy production and polypropylene fiber, was evaluated based on a set of physical and technical indicators. A comparative analysis of the results of production tests of the composition PV+(1.7% AR122+0.2%povidone-K30+15%MK-95)+PF by 0.7% compared with the control factory version revealed the following patterns: an increase in compressive strength by 40.7%; a 32.2% increase in flexural tensile strength; The coefficient of conditional jump tensile strength decreased by 38.5%, and the water absorption of the material decreased by 54%; the water resistance level increased by three pressure levels; the frost resistance index doubled.

The results of the study:

A cast modified concrete with a triple additive system (hyperplasticizer, silica, polymer, polypropylene fiber) has been developed, which has high physical and mechanical characteristics: compressive strength — 67.1 MPa, bending strength — 7.28 MPa, water absorption — 2.1%, frost resistance — F600, water

resistance — W12. The use of ferroalloy production waste has further increased the moisture resistance and durability of the material.

Optimization of the granulometric composition of the cement binder (with fraction size: 12 microns — 15%, 6.6 microns — 75%, 4.9 microns — 10%) and accurate selection of dosages of modifying additives (0.2% povidone-K30, 0.7% polypropylene fiber) provided increased strength while reducing cost.

X-ray phase analysis showed a 26% decrease in the portlandite content and an active development of the Pozzolan reaction. After 6 months, the degree of hydration reached 82%, which confirms the presence of clinker reserve and the potential of the material for long-term durability.

Electron microscopic analysis revealed a dense microstructure of the cement conglomerate with evenly distributed fine porosity (0.1–0.5 microns) and a stabilized ettringite phase (60-70 nm), which helps to reduce cracking.

Mechanical tests confirmed an improvement in compressive and flexural strength compared to control formulations: an increase of 29% and 32.4%, respectively. The addition of polypropylene fiber provided an additional increase in strength and increased deformation resistance.

The composite showed high resistance to chemical degradation (NaCl, HCl, water, Na_2so_4), with minor weight and strength losses. Production testing at Temirbeton-1 LLP proved the applicability of the technology in real conditions. The economic effect amounted to 2,572 tenge per m3 of products.

Prospects: the use of an expanded range of secondary mineral components to increase the strength, environmental friendliness and cost-effectiveness of cast concrete.