ANNOTATION

dissertation on the topic: "Development of the composition and technology for the production of a clinker-free binder for the concrete from industrial waste"
for the degree of Doctor of Philosophy (PhD)
in the educational program 6D073000 – "Production of Construction Materials, Products, and Structures"

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The thesis is devoted to the development of the composition and technology for the production of clinker-free binder from man-made industrial waste and its use in the production of reinforced concrete products and structures.

The purpose of the dissertation is to develop a scientific and technological justification for modifying the composition of a clinker-free binder by using complex additives, including a silica-containing modifier and a superplasticizer for concrete based on man-made industrial waste.

Research objectives:

- to study the chemical and phase composition, hydraulic and pozzolanic activity of blast furnace granular slags and to evaluate the possibility of their use for the production of clinker-free binders and concretes based on them;
- to evaluate the possibility of obtaining slow-hardening binder compositions based on blast-furnace granular binders and to identify the main ways to intensify hydration and hardening of man-made waste;
- to substantiate the effectiveness of mechanical activation of technogenic raw materials of various compositions and chemical activation as ways to increase its activity under natural hardening conditions;
- to establish patterns of changes in the physico-mechanical properties, phase and structure formation of clinker-free binders based on man-made waste depending on the degree of dispersion of the binder, the amount of the hardening activator - gypsum stone and the hardening time;
- to determine the patterns of influence of a microdispersed silica-containing modifying additive on changes in the phase composition, structure and properties of a clinker-free binder and concrete based on it;
- to develop a technology for synthesizing a nanoscale additive to modify the structure and properties of a clinker-free binder and concrete based on it;
- to investigate the basic physical and mechanical properties and operational characteristics of concrete based on a clinker-free binder using modifying additives and to develop the technological foundations of its production;
- to conduct pilot testing of the results of scientific research and to assess the technical and economic efficiency of using man-made waste in the production of clinker-free binder and concrete based on it.

Methods of achieving set goals:

The study of domestic and international experience aimed at exploring the possibilities of obtaining clinker-free lime-silica binders from man-made waste, confirmed by patents, copyright certificates for inventions.

The use of electron microscopic and chemical studies, methods of X-ray phase analysis, etc.

All tests were carried out in accordance with state standards and other regulatory documents of the Republic of Kazakhstan. The tests were carried out in accredited laboratories: Karaganda Technical University named after Abylkas Saginov, the Center for Collective Use named after Professor Yu.M. Borisov (Voronezh State Technical University, Russia), the National Center for Expertise and Certification (Kazakhstan).

Scientific results submitted for dissertation defense:

– scientific and technological foundations of managing the structure formation of concrete based on a clicker-free binder using man-made waste through the use of modifying silica-containing additives of various levels of dispersion;

– patterns of changes in the physico-mechanical and operational properties of clinker-free binders using complex modifying additives, including silica-containing modifier and superplasticizer, for concretes from man-made industrial waste;

– patterns of changes in the phase composition and structure formation of modified clinkerless binder;

– the mechanisms of phase formation in the lime – blast furnace granular slag - mineral modifier system under natural hardening conditions, taking into account the chemical and mineral characteristics of man-made raw materials and modifying additives;

– compositions and properties of modified concrete mix and cured concrete based on clinker - free binders;

– assessment of technical and economic efficiency and approbation of proposed technical solutions.

Scientific novelty of the dissertation: the possibility of using blast furnace granular slag as the main raw material for the production of clinker-free binder and concrete based on it, the properties of which do not differ from those of cement concrete, is theoretically substantiated and experimentally proven.

1. The scientific and technological foundations of the modification of a clinker-free binder are proposed, which consist in the use of modifying silica-containing additives of various levels of dispersion as regulators of structure formation processes, which ensures the production of concrete with increased technical and economic efficiency. The physico-chemical activity of micro- and nanodisperse additives determines the optimization of the microstructure and the formation of a polymineral binder of rational composition and morphology.

2. It has been proven that mechanical activation of blast furnace granular slag accelerates the process of its hardening and the rate of interaction with lime to form predominantly low-base calcium hydrosilicates of the CSH(I) type. The introduction of gypsum stone additives into the binder as a hardening activator increases the strength of silicate stone due to the formation of calcium hydrosulfoaluminates.

3. The peculiarities of the effect of an active mineral additive, microsilicon, on increasing the viscosity and required plastic strength of a clinker–free binder using man-made waste have been established. This is due to the optimization of the

granulometric composition of the binder by regulating the content of microsilicon in the lime – blast furnace granular slag system with the formation of a dense binder package and the formation of the gel structure of the hydrate stone.

4. A technology for the synthesis of a complex nanomodifier based on a nanoscale SiO2-H2O system has been developed and its effectiveness in modifying the composition and structure of a clinker-free binder, which improves its properties, has been proven. The use of a superplasticizer in the composition not only reduces the water-binding ratio, but also stabilizes the nanomodifier, prolonging the preservation of its properties.

5. Using the method of mathematical experimental planning, optimal compositions and conditions for the production of a clinker-free binder have been established, which make it possible to obtain concrete based on it with improved physical, mechanical and operational characteristics.

6. Patterns of changes in the physico-mechanical parameters of clinker-free binders have been identified, depending on the type and amount of modifying additives that ensure the formation of an optimal hydrate stone structure.

7. The mechanism of phase formation in the lime-blast furnace granular slag-mineral modifier system has been established under normal hardening conditions, taking into account the dispersion and physico-chemical activity of modifying additives.

The novelty and significance of the study lies in the fact that a comprehensive study of clinker-free binders with modifying additives of various levels of dispersion and physico-chemical activity has been carried out to obtain concrete with improved physico-mechanical and operational properties. Optimal granulometric compositions of binders have been selected, which use modifier additives to improve the composition, structure and properties of composites based on them.

Practical significance. Resource-saving compositions and energy-efficient technology of concrete production for reinforced concrete crossbars and beams using a clinker-free binder with modifying additives have been developed. The research is of practical value for the construction industry and for enterprises producing concrete and reinforced concrete products and structures. The production of concrete based on a clinker-free binder with the required physical, mechanical and operational properties will reduce the cost of production and improve the environmental situation through the disposal of man-made industrial waste. As a result of the dissertation work:

1. An assessment of man-made industrial waste as a resource-saving, energy-efficient raw material for the production of clinker-free binders and concrete based on them has been carried out.

2. A mechanism for the synthesis of a mineral nanomodifier using sol-gel technologies for the formation of high physico-chemical activity and polydispersity of a clinker-free binder is proposed and its stabilization in the presence of surfactants is evaluated.

3. Concrete compositions based on a clinker-free binder have been developed, including modifying silica-containing additives of various degrees of dispersion and a polycarboxylate-based superplasticizer.

4. The dependences of the properties of concrete on a clinkerless binder on the type and amount of modifying additives have been established.

5. The technical specifications "Heavy concrete based on a clinkerless binder based on man-made industrial waste for the production of reinforced concrete crossbars" were developed and approved, on the basis of which pilot testing of technical solutions was carried out at the production site of “KKK Beton” LLP. Also, the technical specifications "Heavy concrete based on a clinkerless binder based on man-made industrial waste for the construction of reinforced concrete monolithic columns", on the basis of which pilot testing of technical solutions was carried out at the “Kazdorstroytech” LLP production site.

6. The assessment of the technical and economic efficiency of obtaining and using a clinker-free binder on man-made industrial waste has been carried out. The proposed solutions are confirmed by the patent of the Republic of Kazakhstan for invention No. 33928 "Clinkerless binder from man-made industrial waste".

The research results have been introduced into the educational process of Karaganda Technical University named after Abylkas Saginov in the disciplines of "Binders" and "Resource–saving technologies for the production of building materials" for the educational program "Production of building materials, products and structures".

The degree of reliability of the research results.

The reliability of the scientific data obtained is confirmed by current regulatory documents, the use of various research methods using certified and trusted laboratory equipment. The reliability of the results is also confirmed by the high degree of correspondence between the calculated and experimental data, the stability of reproducible values with a 95% probability in large-scale test series. Laboratory studies were conducted in the laboratories of the Department of "Building Materials and Technologies" of Karaganda Technical University named after Abylkas Saginov, the Department of "Engineering Structures, Construction Technologies and Materials", accredited testing centers of Voronezh State Technical University (Voronezh). The work on testing the resulting concrete was carried out in the laboratory of the enterprise "Complex Expertise Company" LLP. The results of the work do not contradict the scientific conclusions and provisions established by leading scientists in the field of binders, production of concrete and reinforced concrete products, as well as monolithic concreting, which indicates their validity and reliability.

The applicant's personal contribution consists in the development of goals and objectives, the choice of research methods, as well as scientific and technological principles for the production of clinker-free binders on man-made industrial waste. The results of all laboratory studies and tests were obtained by the author personally or with his direct participation. The approbation of the developed technology in the conditions of industrial production has been carried out. In the published articles, the author co-authored the results of experimental research, analysis, preparation, registration, sending and maintenance of materials.

Approbation of the work. The main results of the dissertation were reported at 4 conferences:

1. Теоретические основы использования отходов промышленности для производства вяжущих веществ. Materials of the XV international scientific and practical conference – «FUNDA-MENTAL AND APPLIED SCIENCE-2019» (30 окт. - 07 нояб. 2019 г.). – Sheffield: Science and education LTD, 2019, Volume 13. P. 40-42.

2. Процессы гидратации, протекающие в бесклинкерном вяжущем из отходов промышленности. Materials of the XVI international scien-tific and practical conference – «SCI-ENCE AND CIVILIZATION-2020» (30 янв. - 07 дек. 2020 г.). – Sheffield: Science and education LTD, 2020, Volume 8. P. 34-36.

3. Высокопрочные бетоны на бесклинкерном вяжущем из отходов промышленности. Труды Междунар. науч.-практ. конф. «Интеграция науки, образования и производства – основа реализации Плана нации» (Сагиновские чтения №12), Караганда: КарГТУ, 2020. - Ч. 2. - С. 389-391.

4. Особенности микро- и макроструктуры шлакощелочных вяжущих и бетонов на их основе. Труды Международной научно-практической конференции «XVI Сагиновские чтения. Интеграция образования, науки и производства» (часть 3). -Караганда, С. 258-261

The main provisions of the thesis have been published in 5 publications:

1. Clinkerless slag-silica binder: hydration process and hardening kinetics. Magazine of Civil Engineering. 2019. 92(8). Pp. 96–105. DOI: 10.18720/MCE.92.8;

2. Морозостойкость бетона на бесклинкерном вяжущем из техногенных отходов промышленности. Труды университета. - Караганда: КарГТУ, 2020. - № 2 (79). - С. 106-109;

3. Clinkerless slag-silica binder: hydration process and hardening kinetics (part 2). Инженерно-строительный журнал, 2020, № 5(97). Номер статьи 9712. DOI: 10.18720/MCE.92.8;

4. Study of the hydrophysical properties of heavy concrete modified with complex organo-mineral additives. International Journal of GEOMATE, Dec., 2024 Vol.27, Issue 124, Japan, pp.24-31. DOI:10.21660/2024.124.4561;

5. Параметры, влияющие на стойкость бетонов к агрессивным средам. Труды университета. - Караганда: КарТУ, 2024. - №3 (96). –С. 175-181.