ABSTRACT

of the dissertation work
on the topic: “Development of the Production Technology of Highly Porous Polystyrene Concrete for Energy-Efficient Exterior Wall Panels”
submitted for the degree of Doctor of Philosophy (PhD)
under the educational program 8D07302
“Production of Building Materials, Products and Structures”

The priority areas of development in the science field of the Republic of Kazakhstan for 2024–2026 are identified as: “Ecology, Environment and Rational Use of Natural Resources” and “Energy, Advanced Materials and Production.”

The objective of the dissertation is to develop a scientifically substantiated technological solution ensuring the production of highly porous lightweight concrete with polystyrene aggregate, characterized by enhanced physical-mechanical and deformation properties, as well as the three-layer wall panels using it as a thermal insulation layer through the incorporation of a comprehensive organo-mineral additive composed of microdispersed mineral components capable of strengthening and densifying the cement composite and an organic component that increases the workability of the mixture.

To achieve this objective, the following tasks were set:

- to analyze the effect of varying amounts of chemical admixtures on the workability of the concrete mixture and the concrete strength;
- to develop and optimize the composition of highly porous polystyrene concrete (HPPC) with specified deformation and physical-technical characteristics;
- to investigate the influence of raw material components on the properties of lightweight and heavyweight concrete;
- to develop a technology for panel manufacturing, taking into account a quality control system at all production stages;
- to study the physical and technical characteristics of the obtained HPPC.

Research methods:

The research methods included laboratory, computational, experimental, comparative, multifactorial experimental design method, X-ray phase analysis, and SEM analysis. A comprehensive theoretical study was conducted on the multilayer exterior enclosure structure of a three-layer panel made of highly porous polystyrene concrete, developed using the new technology, in comparison with traditional panels, using the ELCUT 6.6 software package and the Maple computer algebra system.

The research methodology is based on both theoretical and empirical methods, built on generalization, comparative analysis, experimentation, as well as the principles of a system approach, mathematical modeling, planning, and experimental

data processing. The work was conducted using a system-structural approach in construction materials science, which considers the relationships between the composition, structure, and characteristics of materials, enabling the effective optimization of their production and usage.

Experimental studies were conducted on laboratory samples using modern analytical methods, including electron microscopy and chemical analysis. This comprehensive approach ensures the acquisition of more accurate and reliable data, allowing the properties and quality of materials to be assessed with a high degree of confidence.

All tests were conducted in accordance with state standards and other regulatory documents of the Republic of Kazakhstan. The tests were conducted in accredited laboratories.

The scientific novelty consists of:

1. A scientifically substantiated and experimentally proved technological solution for producing highly porous modified lightweight concrete with polystyrene aggregate, possessing enhanced performance characteristics, is provided. This solution consists of using a composite binder containing 60% Portland cement and 40% ground granulated blast furnace slag as a binder, and modifying a mixture of air-entraining and superplasticizing modifiers. The composite binder is produced by dry mixing Portland cement with granulated blast-furnace slag, pre-ground to a particle size comparable to Portland cement, exhibiting a chemical affinity for clinker minerals and their hydration products, as well as pozzolanic activity. The mixed binder is then mixed with expanded polystyrene aggregate, mixing water, and an aqueous solution of a complex organic (air-entraining and plasticizing) additive. This process results in highly porous lightweight concrete with standard performance characteristics (compressive strength increases to 2 MPa, thermal conductivity to 0.095 mW/m^{o}C, and vapor permeability to 0.087 mg/m*h*Pa) due to the formation of additional crystalline hydrates, which strengthens the cement system.

2. It was established that the use of a mixed binder (60% Portland cement and 40% finely dispersed granulated blast-furnace slag) leads to a change in the phase composition of the cement system (an increase in the content of calcium hydrosilicates and a decrease of portlandite) and leads to its strengthening.

4. The influence of formulation and technological factors, namely the composition and method of preparation of the mixed binder and the content of a complex organic additive consisting of an air-entraining and plasticizing component in a 1:1 ratio, on the formation of the cement matrix structure during the formation of crystalline hydrates was established: the organic component reduces water demand and changes the porosity of the cement system; and finely dispersed granulated blast-furnace slag affects the formation of the crystalline structure in the cement stone.

Scientific statements submitted for dissertation defense:

- the composition of highly porous polystyrene concrete as a thermal insulation layer for three-layer wall panels;
- the effect of a complex additive on the physical and mechanical properties of highly porous polystyrene concrete;
- a technological solution for producing three-layer wall panels, which reduces the production cost of the panels through the use of an optimized composition for the thermal insulation layer and the automation of operations.

Practical significance:

- a scientifically proved composition of highly porous polystyrene concrete was developed and proposed for use as a thermal insulation layer for energy-efficient wall panels;
- a raw mix for thermal insulation products was proposed for use (utility model patent No. 9341 "Raw Mix for Thermal Insulation Products");
- a certificate of record registration into the state register of rights to objects protected by copyright No. 66084 was received;
- a technological solution for producing three-layer wall panels was developed, it reduces the cost of production and improves the environmental quality through the use of industrial waste;
- an implementation report was obtained for the introduction of three-layer wall panels with a layer of highly porous polystyrene concrete using the developed technology, and the proposed solutions were tested in production;
- the research results were implemented in the educational program 7M07303 - “Production of Building Materials, Products and Structures” of Abylkas Saginov Karaganda Technical University NJSC within “Modern Materials Based on Local Raw Materials” discipline.

Personal contribution of the candidate is in developing the objectives and tasks, selecting the research methods, as well as establishing the scientific and technological principles for producing highly porous polystyrene concrete from industrial waste. All laboratory studies and tests were carried out personally by the author or with his direct participation. The developed technology was tested under industrial production conditions. In co-authored published articles all the experimental research results, analysis, preparation, formatting, submission, and follow-up of the materials belong to the author.

Reliability of the research results

The reliability of the obtained scientific data is confirmed by current regulatory and legal documents, the use of modern research methods, and certified and calibrated laboratory equipment. The studies were conducted in accredited laboratories of Technical Control of Safety of Buildings and Structures LLP in Karaganda, as well as at the Federal State Budgetary Scientific Institution “Institute of Solid State Chemistry

and Mechanochemistry" of the Siberian Branch of the Russian Academy of Sciences (ISSCM SB RAS) during a scientific internship in Novosibirsk. The results of the laboratory studies were further validated through pilot-industrial testing.

Work Testing. The main results of the dissertation have been published in the following journals/conferences:

- "Analysis of the Efficiency of Using Blast Furnace Slag as a Component of Composite Binder for Polystyrene Concrete." University Proceedings.- Karaganda: KarTU, 2023. - #4 (93). – pp. 201-207;
- "Effect of Heat Treatment of Expanded Polystyrene Concrete on its Compressive Strength", Technobius, 2024, 4(2), 0059, DOI: https://doi.org/10.54355/tbus/
- "Study of Various Compositions of Polystyrene Concrete and Their Effect on the Physical and Technical Properties of Lightweight Concretes." University Proceedings.- Karaganda: KarTU, 2024. - #4 (97). – pp. 167-175;
- "Computational Research of the Efficiency of Using a Three-Layer Panel Made of Highly Porous Polystyrene Concrete". Materials, 2024, 17(16), 4133;
- "Opportunities for the Development of Polystyrene Concrete and Complex Modifier." XV Proceedings of the International Scientific and Practical Conference "XV Saginov Readings: Integration of Education, Science, and Production" Karaganda, Kazakhstan, Section 3, pp. 307-308;
- "Analysis of the Energy Efficiency of a Building Made of a Three-Layer Panel from Highly Porous Polystyrene Concrete". International Scientific and Practical Conference "Smart Cities and Sustainable Regional Development" Published online: September15, 2025, ISBN: 97 8-5-6053915-6-2, DOI: 10.63550/ ICEIP.2025.67.16.040.
- Patent of the Republic of Kazakhstan for the "Raw Material Mixture for Thermal Insulation Products" utility model # 9341 dated November 29, 2024.
- Certificate of entry in the state register of rights to objects protected by copyright # 66084 dated January 8, 2026.