

## ABSTRACT

of the thesis

on the topic: "Technology of granular ceramic aggregate based on clay of Western Kazakhstan" submitted for the degree of Doctor of Philosophy (PhD) in the specialty 6D073000 – "Production of building materials, products and structures"

The relevance of the research topic is determined by the priority areas of science development in the Republic of Kazakhstan for 2024–2026, namely: «Ecology, Environment and Rational Use of Natural Resources» and «Energy, Advanced Materials and Manufacturing».

**The aim of this dissertation is** to develop a production process for granular ceramic aggregate based on clays from Western Kazakhstan, ensuring that the material meets the required physical, mechanical, and performance properties.

**To achieve this goal, the following objectives were set:**

- to analyze the current state and future prospects of technologies for producing granular ceramic fillers;
- to investigate the physical-mechanical and chemical-mineralogical properties of loam from Western Kazakhstan and man-made raw material components;
- determining the influence of ceramic body composition and heat treatment conditions on sintering, structure formation, and pore formation processes;
- identifying patterns in changes to the strength, thermophysical, and performance characteristics of granular ceramic aggregate;
- development of optimal compositions and technological parameters for the production of granular ceramic aggregate;
- assessment of the potential for practical application of the developed material in construction.

### **Research methods.**

- a literature review of domestic and international sources, including an examination of patents for inventions and utility models, as well as global experience in researching the use of clay-rich rocks mixed with industrial waste in the production of building materials;
- investigation of the chemical, mineral, and particle size distribution of clays from Western Kazakhstan; study of the physicochemical characteristics of fly ash from thermal power plants and granulated blast furnace slag; conducting electron microscopic studies and testing in accredited laboratories;
- pilot-scale testing of granulated ceramic aggregate for use in concrete;
- description of methods for the experimental production of granulated ceramic aggregate;
- characterization of the methods used to analyze the structure and properties of raw materials and finished products.

### **Scientific novelty:**

- the possibility of producing a granular ceramic aggregate for construction purposes, which ensures the formation of a strong microporous structure under

optimal heat treatment conditions, has been scientifically substantiated and experimentally confirmed.

- the patterns of influence of fly ash from thermal power plants in the range of 10–30 wt.% on the sintering and structure formation processes of granular ceramic aggregate have been established, manifested in the intensification of glass phase formation and controlled pore formation.
- a complex strengthening effect of granulated blast furnace slag in ceramic compositions has been revealed, due to its glass-phase state and participation in the formation of a glass-crystalline matrix during firing.
- the mechanism for the formation of structure-strengthening crystalline phases (mullite, anorthite, wollastonite, and the glass phase) during firing in the temperature range of 950–1100°C has been established, which ensures an improvement in the physical, mechanical, and thermophysical properties of the filler.
- optimal compositions of ceramic slurries and technological parameters for the production of granular ceramic filler have been determined.

**Scientific propositions put forward in the dissertation defense:**

- theoretical foundations have been developed for the production of granular ceramic aggregate based on loam, including the stages of raw material preparation, granule forming, drying, and high-temperature firing, which ensure the formation of a strong, microporous material structure.
- the use of loam as the main raw material component for the production of granular ceramic filler without the use of scarce natural fillers and traditional fluxes.
- the optimal compositions of fly ash and granular blast furnace slag in ceramic masses (10–30 wt.%) that ensure an increase in strength and a reduction in the average density of the granular ceramic aggregate, achieved through the formation of a glass-crystalline matrix and the burnout of residual carbon.
- the use of the developed granular ceramic filler in lightweight concretes and building structures is demonstrated, as well as its resource-saving and environmental efficiency due to the utilization of man-made mineral waste.

**Practical significance:**

- optimal compositions of ceramic slurries and processing conditions have been developed to produce granular ceramic aggregate with specified physical, mechanical, and thermophysical properties;
- formulations and technology for granular ceramic aggregate as a coarse aggregate in lightweight and structural-thermal insulation concretes have been developed;
- the raw material base of the ceramic industry has been expanded by incorporating up to 30% of man-made mineral waste, such as fly ash from thermal power plants and granulated blast furnace slag, into production, ensuring resource-saving and environmental benefits by reducing waste storage volumes;
- technical specifications and technological regulations for the production of granular ceramic aggregate have been developed, along with an assessment of the technical and economic feasibility of implementing the technology.

**The candidate's personal contribution** lies in formulating the research problem, developing a methodological approach, conducting experimental studies, analyzing

and synthesizing the results obtained, as well as formulating scientific conclusions and practical recommendations regarding the technology for producing granular ceramic aggregate from clay-rich rocks found in the Western Kazakhstan region.

### **Reliability of the research results.**

The laboratory tests were conducted at the testing and research laboratory at the Zhanagir Khan ZKATU. The reliability of the experimental data is ensured by the use of standard and proven research methods that comply with current national and international standards, as well as by the use of modern analytical and testing equipment, and has been confirmed by pilot-scale industrial tests.

**Presentation of the work. The main findings of the dissertation have been published in the following journals and conference proceedings:**

- «Technology Of Granulated Ceramic Aggregate For Concrete Based On Clay Of Atyrau Deposit Of Western Kazakhstan.» Architectural Studies. - 2024. - Vol. 10, № 2. - P. 162-171 (Scopus). DOI: 10.56318/as/2.2024.162 DOI: 10.56318/as/2.2024.162 Процентиль 62, Q3
- «Influence of a powder-forming additive on the physical-mechanical properties and structure of a ceramic material». Functional Composites and structures. - 2023. - Vol. 5.Iss.3.-P.1-10.-ISSN2631-6331.DOI: 10.1088/2631-6331/acf113 процентиль 67
- «Possibility of producing sintered fine porous granulated ceramic filler using ash of thermal power stations in combination with clay rocks» International Journal of Mechanical and Production Engineering Research and Development. - 2019. Is. 4. Vol. 9. - P. 1087-1096. - ISSN 2249-6890
- «Study of raw materials with the aim of obtaining ceramic filler and heat-insulating and structural wall ceramics» International Journal of Mechanical and Production Engineering Research and Development. - 2019. Is. 5. Vol. 9. - P. 1057-1064. - ISSN 2249-6890
- “Development of Ceramic Composite Formulations for the Production of Ceramdor.” Science News of Kazakhstan, scientific and technical journal. ISSN 1560-5655, No. 3(141), 2019. – Almaty. – pp. 161–165
- “Study of the drying properties of ceramic slurry in the ‘Loess-like loam – Ekibastuz GRES ash’ system.” – Almaty. – pp. 146–153. / Bulletin of the National Engineering Academy of the Republic of Kazakhstan No. 3 (77), 2020. doi.org/10.47533/2020.1606-146X.19
- “The Effect of the Dispersion of Blast Furnace Granulated Slag from ArcelorMittal Temirtau JSC on the Physical and Mechanical Properties of Ceramic Road Material.” MRNTI 67.15. News of Science of Kazakhstan, scientific and technical journal. ISSN 1560-5655, No. 4(147), 2020. – pp. 146–153. Almaty.
- “Study of Raw Material Compositions for Ceramic Aggregates and Thermal Insulation and Structural Wall Ceramics.” Penza State University of Architecture and Construction. Regional Architecture and Construction, No. 4. – 2021. – pp. 54–62. <https://www.elibrary.ru/>

- “Prospects for the use of loess-like loams from Western Kazakhstan in the production of keramdor.” Traditions and Innovations in Construction and Architecture: Construction Technologies: Collection of Articles. – Samara. – 2019. - pp. 158–163 (Samara)
- “Use of Granulated Blast Furnace Slag in Ceramic Compounds for the Production of Ceramic Aggregate (Keramdor).” International Journal of Applied and Fundamental Research. - 2019. - No. 10. - pp. 164–168 (Penza). - ISSN 1996-3955
- Patent No. KZ 5168—“Method for Producing a Ceramic Filler,” July 17, 2020, Ministry of Justice of the Republic of Kazakhstan. Application 2020/0496.2, filing date: May 26, 2020, published July 17, 2020, Ministry of Justice of the Republic of Kazakhstan, Patent Holder: ZHANGIR KHAN ZKATU National Academic Institution