

OUTLINE.

dissertation for the degree of Doctor of Philosophy (PhD)
in the educational programme 8D07302 - 'Production of Building Materials,
Products and Structures'

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INVESTIGATION OF STRUCTURE FORMATION PROCESSES AND PREDICTION OF CERAMIC BRICK PROPERTIES USING OVERBURDEN ROCKS FROM COAL MINING

The aim of the thesis work is to develop and substantiate scientific principles and technological parameters for the production of ceramic bricks from overburden rocks of coal mining with improved performance characteristics.

Objectives of the study:

- to study the material composition, physical, mechanical, chemical, mineralogical, and other properties of overburdened rocks of different lithological types and horizons;
- to reveal the influence of characteristics of molding masses from overburdened rocks on qualitative indicators of ceramic bricks;
- to determine the optimal compositions of charge and technological parameters for the production of ceramic wall products, including matrix structure, based on overburden rocks of coal mining with the required properties;
- to reveal the influence of organic and chemical additives on the processes of formation of ceramic mass structures during molding, drying, and firing ceramic bricks from overburden rocks of coal mining;
- to establish the influence of drying properties on the processes of formation of condensation structure of ceramic bricks from overburden rocks of coal mining;
- to develop technological parameters and modes of firing, providing the directed course of processes of formation of optimal crystallization structure of ceramic products from overburdened rocks of coal mining;
- to investigate the main physical and mechanical properties and operational characteristics of finished products;
- to carry out experimental-industrial approbation of the results of scientific research and evaluate the technical and economic efficiency of the use of overburden rocks of coal mining in the production of ceramic bricks.

Research Methods.

In the present dissertation work the research methods widely approved and shown to be effective in applied physicochemical studies of building materials were used, these are electron-microscopic and chemical studies, methods of differential-thermal analysis, IR-spectrometry, X-ray-phase, etc.

All tests were carried out by state standards and other regulatory documents of the Republic of Kazakhstan. The tests were carried out in accredited laboratories.

Scientific results (scientific provisions) put forward for defence:

- dependence of changes in chemical, mineralogical-mineralogical composition, and physical-mechanical properties of overburden rocks on their lithological types and horizons of occurrence, allowing the use of coal mining waste as the main raw material for the production of ceramic bricks;
- structural and mechanical characteristics of the masses based on overburden rocks with additions of coal shale, waste of chemical production - aluminum oxychloride and Kalkaman clay, providing an increase of strength and frost resistance of ceramic products;
- requirements to ceramic masses based on overburdened rocks of coal mining and clay raw materials of optimal granulometric composition, providing dense packing and defect-free molding of products including those with matrix structure;
- the results of research on the processes of transformation of raw material consisting of granules based on overburden rocks of coal mining, covered with clay shell, into ceramic matrix composite after firing, having a transition layer on the boundary of core-matrix contact;
- the developed technological scheme of production of ceramic wall bricks based on overburdened rocks of coal mining by methods of plastic extrusion of multi-component charges.

The main findings of the study are.

Theoretically substantiated and experimentally proved the possibility of using overburdened rocks of coal mining as the main raw material for the production of ceramic bricks.

1. the dependence of changes in physical and mechanical properties, chemical and mineralogical composition of overburdened rocks on their lithological types, and horizons of occurrence is substantiated.
2. The features of change of structural and mechanical characteristics of masses from overburden rocks of coal mining at introduction in their structure as additives of coal shale, aluminum oxychloride, and Kalkaman clay, expressed in a decrease of plastic viscosity, a decrease of rigidity and improvement of the molding ability of masses that provides an increase of strength at compression up to 47,5-54,2 MPa water absorption from 9,1 to 7,2 %, frost resistance up to 100 cycles are established.
3. With the use of mathematical methods of planning experiments the optimum granulometric compositions of masses based on overburden rocks providing dense packing, defect-free molding, drying, and firing of ceramic products are established.
4. The algorithm of structure formation (coagulation, condensation, and crystallization) at molding, drying, and firing of ceramic composites of optimum compositions based on overburden rocks is presented.
5. Regularities of obtaining ceramic products from overburdened rocks by methods of plastic extrusion and semi-dry pressing are revealed. Peculiarities of matrix structure formation when using coal mining wastes.
6. Heat treatment regimes providing obtaining ceramic products with given properties are developed.

The novelty of the research lies in the fact that a comprehensive study of overburden rocks of coal mining as a basic, environmentally safe raw material for the production of composite ceramic products has been carried out. Optimal granulometric compositions in which additives-modifiers are used to adjust technological properties and improve the quality of finished products have been selected.

Practical significance. Resource-saving compositions and energy-efficient technology of composite building ceramics production based on overburden rocks of coal mining and additives have been developed. The research is of practical value for the enterprises of the coal industry producing overburdened rocks in the form of production waste. They can significantly reduce the costs of transport, storage of waste, reduce environmental payments. The ceramic industry, can reduce the cost of production and compensate for the lack of conditioned clay raw materials in the production of ceramic products, improving the environmental situation.

As a result of the thesis work:

1. Overburden rocks from coal mining as a resource-saving, energy-efficient raw material for the production of ceramic bricks have been evaluated.

2. The compositions of ceramic charge, including overburden rocks of coal mining, carbonaceous rocks, aluminum oxychloride, and plastic clay for the production of ceramic bricks by plastic, rigid, and semi-dry molding are developed.

3. The features of the formation of coagulation, condensation, and crystallization structures during the molding, drying, and firing of ceramic products have been established.

4. The technological regulations for the production of ceramic bricks from overburden rocks of coal mining have been developed and approved, based on which semi-plant tests have been carried out.

5. The technical and economic efficiency of the use of overburden rocks of coal mining in the production of ceramic bricks has been evaluated.

The proposed solutions are confirmed by the patent of the Republic of Kazakhstan.

Results of the research are introduced in the educational process of Toraigyrov University on the discipline ‘Resource- and energy-saving technologies of building materials production’.

The results of laboratory research are confirmed by pilot tests in the conditions of the brick plant LLP ‘Yer-Min-Brick’ Yereymentau, Akmola region. The produced brick has high physical and mechanical characteristics and meets the requirements of GOST 530-2012.

The developed technology is accepted for implementation by ‘Yer-Min-Brick’ LLP, Yereymentau, Akmola region of the Republic of Kazakhstan.

Dissertation work was carried out by the Priority direction of science development for 2024-2026 years approved in Kazakhstan, ‘Ecology, environment and rational nature management’, Resolution of the Government of the Republic of Kazakhstan from 28 June 2014 № 724 ‘On approval of the Concept of

development of fuel and energy complex of the Republic of Kazakhstan until 2030', the program of development of the territory of the Pavlodar region for 2021-2025 years, approved by the Decision of the Pavlodar Regional Maslikhat, I session, VII convocations of 15 January 2021 № 6/1-VII.

Author's personal contribution:

The author participated in defining the purpose of the work and setting the research objectives, as well as in writing articles, and abstracts and filing a patent application. The author personally obtained the main part of the scientific and practical results of this work, determining both the scientific novelty and practical value of the work as a whole. The results of all laboratory studies and tests were obtained by the author personally or with his direct participation. Scientific and technological principles for obtaining ceramic products from overburdened rocks of coal mining have been developed. Approbation of the developed technology in conditions of industrial production has been carried out. In the published articles in co-authorship, the author owns the results of experimental research, analysis, preparation, execution, sending, and maintenance of materials.

The main results of the thesis were reported at 7 conferences:

1. coal industry waste in the production of facing ceramics. Materials of IV International Scientific and Practical Conference 'Quality. Technologies. Innovations'. - Novosibirsk: NGASU (Sibstrin), 2021. pp. 179-184;

2. Analysis of energy efficiency of building envelopes of JSC 'Station EGRES-2'. AIP Conference Proceedings 2559, 050006, 2022. Scopus.

3. Ecological aspects of using overburden rocks of coal mining in the production of building ceramics. Actual questions of modern construction of industrial regions of Russia: Proceedings of the All-Russian scientific-practical conference with international participation. / Sib. Gos. Hindustr. Un.; Novokuznetsk: Izd. centre SibGIU, 2022. - c. 212-216.

4. Regulation of drying properties of ceramic masses on the basis of overburden rocks of coal mining. Proceedings of the XV Intern. scientific-technical conf. 'Actual issues of architecture and construction'. - Novosibirsk: NGASU, (Sibstrin), 2022. - C. 282-289.

5. Ceramic small-piece products on the basis of local raw materials and industrial wastes. Materials of XVII Intern. scientific-technical conf. of young scientists, dedicated to the memory of Professor V.I. Kalashnikov 'Theory and practice of increasing the efficiency of building materials'. - Penza: PGUAS, 2022. - C. 74-78.

6. Prospects of application of argillites in manufacture of ceramic building materials. Materials of XVIII Intern. scientific-technical conf. of young scientists, dedicated to the memory of Professor V.I. Kalashnikov 'Theory and practice of increasing the efficiency of building materials'. - Penza: PSUAS, 2023. - C. 158-163.

7. Use of TPP ashes in production of building ceramics. Materials of IX All-Russian scientific conference 'Engineering in the Far East of Russia'. - Vladivostok: Far Eastern Federal University, 2024. - C. 217-224.

The main provisions of the dissertation work have been published in 7 printed works:

1. Experience of application of composite materials on the basis of organic and mineral components. Scientific Journal 'Science and Technology of Kazakhstan', NAO Toraigyrov University, No. 2, 2021, pp. 153-159.

2. Production of ceramic bricks on the basis of overburden rocks of coal mining. Scientific Journal 'Internauka', Moscow, Izd. 'Internauka', № 21(244). Part 1. 2022, c. 38-42.

3. Regulation of drying properties of ceramic masses on the basis of overburden rocks of coal mining. Proceedings of the XV inter. scientific and technical conference 'Actual issues of architecture and construction'. - Novosibirsk: NGASU (Sibstrin), 2022. p. p. 282-289. 282-289.

4. Ceramic small piece products on the basis of local raw materials and industrial wastes. Materials of XVII International Scientific and Technical Conference of Young Scientists in memory of Professor V.I. Kalashnikov 'Theory and practice of increasing the efficiency of building materials' - Penza: PSUAS, 2022. - c. 74-78.

5. Study of the properties of overburdened rocks from coal mining: overburden - as a raw material in the production of ceramic bricks. Intern. Journal of GEOMATE, July 2023, Vol. 25, Issue 107, pp.86-94, Scopus Q3. Engineering (Building and Construction) - percentile 39. CiteScore 2022 -1.8, <https://doi.org/10.21660/2023.107.3771>.

6. Strong Structure Formation of Ceramic Composites Based on Coal Mining Overburden Rocks. Journal of Composites Science, 2023, 7(5), 209, Scopus Q2. Materials Science (Ceramics and Composites) percentile 58. CiteScore 2022 - 4.5. <https://doi.org/10.3390/jcs7050209>.

7. Drying properties and formation of condensation structure of ceramic products based on overburden rocks of coal mining. Scientific journal 'Proceedings of the University' KartU named after Abylkas Saginov, -Karaganda, № 2 (91). 2023, c 167-173. KKSON.

Patent for useful model No. 9175 'Raw material mixture for production of building ceramic products'