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Methods for Testing Stonelike Siliceous and Clay Raw Materials Used for Producing Ceramic Bricks and Tiles

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Abstract **– This work describes results of the development of a testing method for stone-like siliceous and clay raw materials used for producing ceramic building materials. The relevance of the use of high-strength products in industrial and residential buildings is emphasized. The analysis of the raw materials selected for the study (flasks, argillite, shale) is presented. A method for assessing bricks and tiles is described.**

Keywords – technique; stone-like raw material; mudstone; shale; clinker; technology; quality silica clay.

I. INTRODUCTION

Individuality, comfort, durability and easiness in maintenance of residential buildings are ensured through the use of modern ceramic products: large-sized ceramic blocks, facing, ordinary and clinker bricks, conventional and clinker tiles, ceramic siding, etc. Figure 1 shows a typical private house in the south of Russia. Its walls are made of ceramic blocks, lined with hand-made ceramic bricks; the roof is covered with ceramic tiles, and the walkways and driveways are lined with road clinker bricks. Ceramic products have the following characteristics: ecological purity, modular dimensions, tensile resistance to compression and bending, frost resistance, vapor permeability, thermal conductivity, a wide range of colors. A set of indicators is used to solve the most complex design and construction tasks and issues [1-6]. There is also a group of clinker products. Additional acid resistance, water resistance and abrasion are imposed on these products depending on the type and purpose of the materials [7, 8].

products, researchers, equipment manufacturers, geological organizations search for new raw materials, develop and implement new technologies and new types of products. Availability of raw materials is a crucial issue in the south of Russia. Analysis of the results of geological surveys and evaluation of clay raw materials used by brick plants in the Southern Federal District showed that there are no high-quality traditional raw materials. There are many limiting factors for developing new deposits. Delivery of raw materials from other regions affects the cost of products. The problem with raw materials for the production of clinker products which should have high strength and low water absorption (2–6%) is acute. In addition, it is important that the raw materials belong to the low-temperature sintering groups, be homogeneous, and meet economic and environmental requirements.

III. RESULTS

We have identified the following factors contributing to the implementation of stone-like siliceous and clay rocks that meet the requirements for the economic and technological components and account for capacities of modern equipment and possible cost of products:

- production availability and logistical leverage of no more than 100 km;
- a simplified flow chart for obtaining the charge with specified parameters;
- good technological properties – low sensitivity to drying, slight shrinkage, good molding properties, etc.;
- effective baking: the ratio of the firing mode to the volume of energy consumed to obtain a given structure and physical and mechanical properties of products;
- required decorative and aesthetic properties of finished products.

Table 1 shows the requirements for clinker bricks and tiles.

Fig. 1. A typical private house in the south of Russia built using ceramic products.

To meet the requirements, manufacturers of ceramic Methods and materials

Studies carried out by scientists of Don State Technical and Southern Federal Universities identified very promising siliceous and stony clay materials which can be used for a wide range of building ceramics, in particular for clinker bricks and tiles [9-12]. The first type is the silica clay-type rocks and their varieties (Fig. 2, 3).

a

б

Fig. 2. Typical gaize deposit in Rostov region: a - general view; b - the structure of the rock formation.

The second type includes argillite-like clays, argillites, tuffargillites, aleurolites, etc. which can be used for producing building ceramics (Fig. 2, 3).

Fig. 3. Layers of argillites and arglite-like clays of the sandstone mero-field

TABLE I. REQUIREMENTS FOR CLINKER PRODUCTS

Indicators	**Type of products**		
	Clinker wall bricks GOST 530	***Climker road bricks GOST 32311***	***Tile GOST R 56688***
Compressive strength, MPa	30–100	–	–
Flexural strength, MPa	> 4.4	> 7.5	> 6-12
Water absorption, %	Not more than 6	Not more than 2.5	Not more than 8-10
Frost resistance, cycles	Not less than 100	Not less than 200	Not less than 100
Acid resistance,%	Not less than 95	Not less than 95	–
Abrasion, g/cm^2	–	Not more than 1.5	–

To assess suitability of deposits of stone-like siliceous and clay raw materials used for producing building ceramics, we identified the main indicators and developed methods for their determination, as well as an algorithm for processing the results. When developing a method for estimating stone-like ceramic raw materials, we analyzed the following groups of rocks: crusts, argillite-like clays, mudstones, shale, aleurolites and transitional varieties. A distinctive feature of these rocks is their interaction with water – they do not soak in water, or soak very slowly – under long-term contact with water or repeated moistening and drying.

In developing main provisions on the use of stone-like ceramic raw materials, we have studied several dozens of typical deposits in the south of Russia and the Volga region, and in the CIS countries. Laboratory and technological samples of rocks were selected at specific fields and were formed from ordinary samples that do not contain plant, soil and other inclusions. Representative samples were selected taking into account characteristics of the mineral source deposit.

The chemical composition of raw materials and calcined samples was determined on the basis of GOST 21216 “Clay raw materials. Test methods”. Petrographic studies were conducted using polarization microscopes. The materials were studied using binocular and digital microscopes. Taking into account the microgranular and cryptocrystalline structures of raw materials and calcined products, X-ray phase and thermal research methods as well as electron microscopy were used. The geological study determined the specific effective activity of natural radionuclides in rocks. In conducting technological studies, the requirements of GOST 21216 “Clay raw materials. Test methods" and GOST 9169" Clay raw materials for the ceramic industry. Classification" were accounted for. In determining the ceramic properties, the requirements and methods of the regulatory and technical documentation were taken into account.

When developing a method for studying stone-like siliceous and clay raw materials, we identified 4 main stages: structure and material composition, technological characteristics and ceramic properties, optimization of technological parameters and product properties, recommendations for the rational use of rocks. Figure 4 shows the types of studies and indicators determined at each stage.

At the stage “Structure and Material Composition”, the chemical and mineralogical composition is identified, rock radioactivity and dissolvability (the main characteristic of the stone-like raw material) and physical and structural characteristics are determined. The chemical composition is determined using standard methods; the mineralogical composition is determined using the methods of derivatographic and X-ray phase analyzes. For some raw materials, we have developed a classification based on the chemical and mineralogical composition. Requirements for the limit content of oxides Al_2O_3, SiO_2, Fe_2O_3, CaO, MgO, SO_3 and their minerals [10, 12] were developed. The classification can be used to predict technological properties and performance characteristics of the products. After soaking capacity has been determined, a scheme of further research is developed. It depends on the type of the raw materials (slow-blending, medium-curving, difficult-opening and non-washing ones).

Description of the rock and its macrostructure (color, density inclusions, size and strength, etc.) is necessary for selection of mining methods and equipment. Radioactivity is an important safety factor when assessing suitability of the field. The raw materials studied meet the requirements of regulatory documents.

At the stage “Technological characteristics”, stone-like raw materials are crushed, divided into fractions; the following indicators “plasticity - formability”, “particle size distribution - compressibility” are determined for various production methods. The degree of grinding of raw materials significantly affects all the technological parameters and properties of ceramic products. We used grids with the following cell sizes: 5, 3, 2, 1, 0.5, 0.25, 0.1 mm which are standard for assessing the soil and grids with a cell size of 5, 2.5, 1.25, 0.63, 0.315, 0.16 mm. Properties are assessed for both monofractional and polyfractional compositions.

It was established that separate groups of stone-like ceramic raw materials (argillite-like clays, clay gaize, clay-carbonate gaize) grinded to the fractions of 0.315–1.25 mm are plastic and suitable for production of ceramic products using a plastic molding method with semi-dry preparation of the charge, as well as for hard molding and "manual molding". For fractions with a grain size of more than 0.63–1.25 mm and up to 2.5 (3) mm, the compression molding method with preparation of press powder is suitable. Press powders with a grain size of more than 2.5 mm from most groups of stone-like raw materials require additional grinding to impart technological properties.

For the plastic forming method, molding moisture, molding pressure, mass temperature, and vacuum depth are determined. For the compression molding scheme, selection of optimal parameters is required - “granulometric composition – molding moisture – pressing pressure”. The monofractional granulometric composition is suitable for the plastic molding method, while the polyfractional one – for the compression method.

Air shrinkage is a technological parameter of the raw material, taking into account e uniformity of changes in the sizes of samples and their volume during the removal of moisture when drying. It is taken into account when determining initial dimensions of the raw materials. It is determined using the standard method or samples-bricks, if the substance is plastic, or samples-cylinders, if the substance is loose.

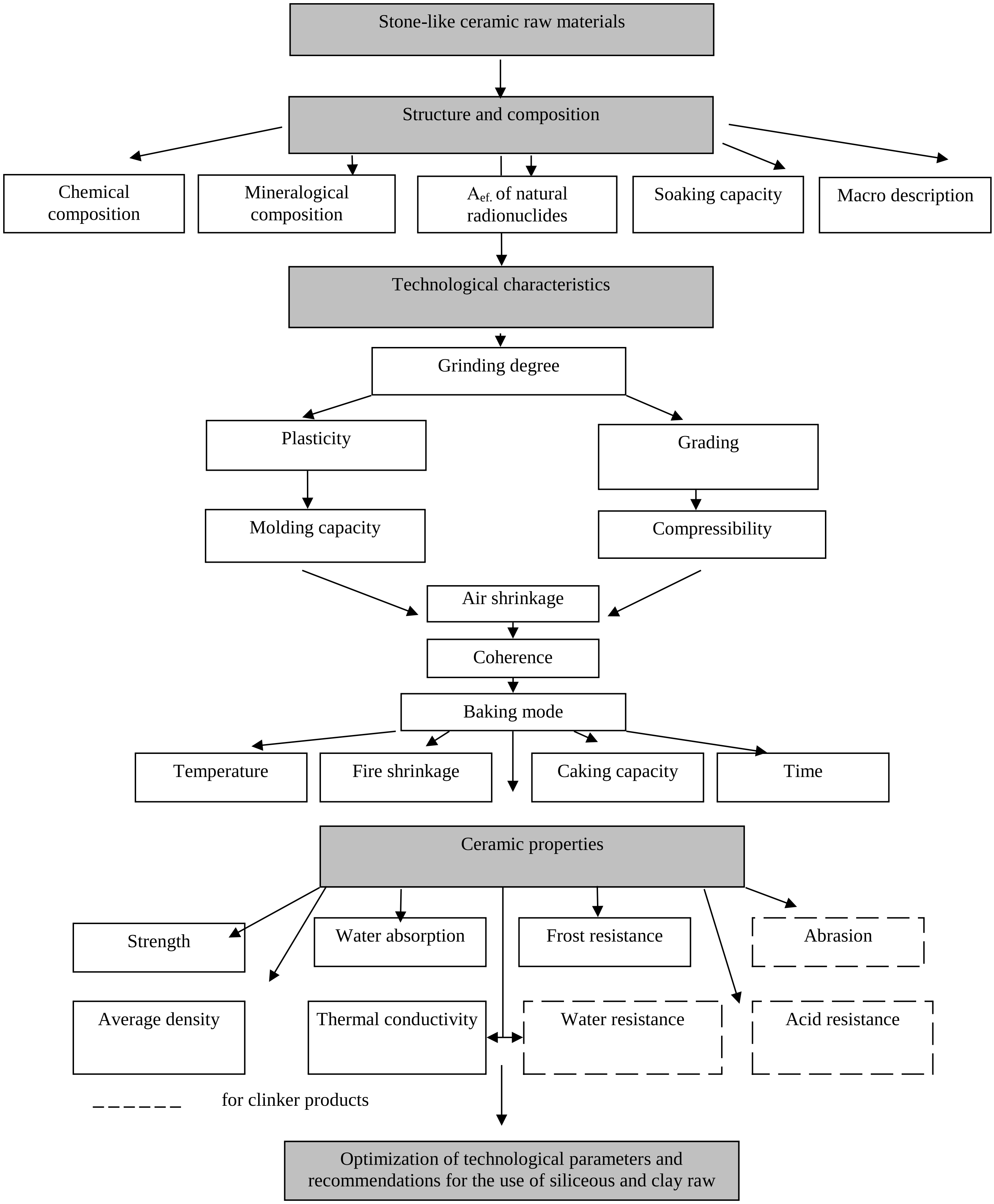

Fig.4. The s cheme of evaluation of stone-like siliceous and clay raw materials

Coherence is a parameter determined for stone-like raw materials by the value of flexural strength of the dried girder samples. It is taken onto account when selecting equipment and implementing the method of movement of products from formation to baking.

The baking mode is a technological factor characterized by the duration and maximum temperatures at each baking stage which determines the structure and properties of finished products. To determine an optimal mode and maximum temperatures, it is necessary to take into account dilatometric analysis results, fire and general shrinkage, and refractoriness. For clinker products, the baking mode is the main factor for achieving high strength and low water absorption without overburning at to 1100-1150 °C. Traditional clay raw materials are low-melting and non-caking. It is not possible to bake clinker materials since there are always signs of burnout or heaving.

At the stage "Ceramic properties", properties of the samples after baking are determined: flexural strength, compressive strength, average density, thermal conductivity, water absorption, frost resistance, etc. For testing raw materials used for production of clinker products, additional abrasion resistance, water resistance, acid resistance are determined and compared with the requirements of regulatory and technical documentation for various types of ceramic products. Strength characteristics of laboratory samples should be 1.5 times higher than requirements for products presented in Table 1. To test the values determined, full-sized products made under laboratory conditions are tested.

At the stage "Optimization of technological parameters and recommendations development", the results are analyzed and possibilities of using stone-like siliceous and clay raw materials for production of ceramic products, including high-strength ones, are assessed. Raw materials are considered both in pure form and with addition of auxiliary components to increase ductility, reduce density and thermal conductivity, water absorption, increase strength and frost resistance, reduce baking temperature. The dependencies of properties of the products on the conditions of preparation of raw materials, parameters of technological processes are formed; the optimal ratio of all factors is selected taking into account resource saving and economic efficiency of production; feasibility of development of a new deposit is discussed. If it is required to develop a new deposit, technological regulations to obtain a mining certificate are developed.

IV. Conclusion

The need for developing a method for assessing stone-like siliceous and clay raw materials used in the the ceramic industry is due to their potential for producing high-quality products. The existing regulations for clay raw materials do not reflect the structure and dependence of the properties of stone-like rocks and their derivatives, the degree of lithification and genesis limiting the use of raw material base.

When testing stone-like siliceous and clay raw materials, it was found that the determination of the content of coarse inclusions by the method used for clay raw materials is not adequate for stone-like rocks. The determination of inclusions in the crushed stone-like rocks requires verification. Experimental data on this indicator are being accumulated. They will be accounted for in the future methodology. The stone-like nature of raw materials and lithification affect the determination of the content of fine fractions, preparation of test samples and particle separation. The data on laser diffractometry are accumulated and processed. The use of this method for assessing stone-like raw materials by geological organizations and testing laboratories will expand the raw material base of building ceramics allow for low cost production of clinker products.

References

[1] F. Pacheco-Torgal, P.B. Lourenço, J.A. Labrincha, S. Kumar, P. Chindaprasirt, "Eco-efficcient Masonry Bricks and blocks", Desing, Properties and Durability, Copyright Elsevier Ltd, 2015.

[2] D.M. de Souza, M. Lafontaine, F. Charron-Doucet, B. Chappert, L. Lima, "Comparative life cycle assessment of ceramic brick, concretebrick and cast-in-place reinforced concrete exterior walls". Journal of Cleaner Production, vol. 137, pp. 70–82, 2016.

[3] M. Pedroso, J. de Brito, J.D. Silvestre, "Characterization of eco-efficient acoustic insulation materials (traditional and innovative)", Construction and Building Materials, vol. 140, pp. 221–228, 2017.

[4] A.A. Semenov, "Trends in the development of brick industry and brick housing construction in Russia", Building Materials, no. 8, pp. 49–51, August 2018.

[5] V.D. Kotlyar, K.A. Lapunova, Ya.V. Lazareva, I.M. Usepeyan, "The main trends and promising types of raw materials in the production of ceramic tiles", Construction Materials, no. 12, pp. 28–31, 2015.

[6] I.F. Schlegel, "On the rational use of clinker bricks (in order of discussion)", Building Materials, no. 8, p. 42–44, 2017.

[7] V.V. Koleda, E.S. Mikhailyuta, E.V. Alekseev, E.S. Tsybul'Ko, "Technological particularities of clinker brick production", Glass and Ceramics, vol. 3–4, pp. 132–135, 2009.

[8] A.L. Murmu, A. Patel, "Towards sustainable bricks production: An overview", Construction and Building Materials, vol. 165, pp. 112–125, 20 March 2018.

[9] Kh.S. Yavruyan1, V.D. Kotlyar, E.S. Gaishun1, "Medium-Fraction Materials for Processing of Coal-Thread Waste Drains for the Production of Wall Ceramics", Materials and Technologies in Construction and Architecture. Materials Science Forum Submitte, vol. 931, pp. 532–536, May 2018.

[10] Yu.V. Teryokhina, B.V. Talpa, A.V. Kotlyar, "Mineralogical and technological features of lithified clay rocks and the prospects for their use as a raw material for the production of building ceramics", Construction Materials, no. 4, pp. 8–10, 2017.

[11] R.J. Galán-Arboledas, M.T. Cotes-Palomino, S. Bueno, C. Martínez-García, "Evaluation of spent diatomite incorporation in clay based materials for lightweight bricks processing", Construction and Building Materials, vol. 144, pp. 327–337, 2017.

[12] B.V. Talpa, "Prospects for the development of the mineral resource base for the production of light-curd wall ceramics in southern Russia", Building Materials, no. 4, p. 10–13, 2016.