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USE OF BASALT AND CLAY MATERIALS IN THE COMPOSITION OF CERAMIC MASSES

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Abstract
The article examines the chemical mineral composition, the formation of crystalline phases of minerals, the basic properties of ceramic masses with igneous rocks and the formation of minerals during the sintering process in the temperature range 950-1150°C. The results obtained indicate that the introduction of iron-containing basalts stabilizes the structure of ceramic slabs and reduces their sintering temperature. According to geological data, kaolins from the Republic of Karakalpakstan are promising for use.

Keywords Basalt, ceramic plate, temperature, sintering, water absorption, shrinkage, kaolin, clay, phase transformations, chemical, X-ray diffraction, electron-microscopic.

INTRODUCTION

In modern conditions of rapidly growing construction rates of residential and industrial buildings, the need for ceramic building materials for various purposes is constantly increasing. The intensive growth of the ceramic materials industry depends primarily on the use of innovative technologies, expansion of the raw material base and involvement in the production of non-traditional materials [1, 2].

In recent years, a number of studies have been devoted to the problems of rational use of natural and mineral resources, the search and expansion of the raw material base for the production of ceramic materials for various purposes through the use of non-traditional types of raw materials, the development of resource- and energy-saving methods and the improvement of existing technologies. According to GOST 13996-2019, the mechanical bending strength of ceramic tiles must be higher than 16 MPa, which limits the scope of application of various raw materials. In this regard, it seems relevant to study the physicochemical, physical and mechanical characteristics of experimental samples of building ceramic masses and determine the influence of basalt rocks on the shrinkage and water absorption of experimental ceramic masses depending on the firing temperature [3, 4].

METHODS

Experimental studies on the development of compositions, production technologies and determination of the main characteristics of ceramic materials based on clayey and basalt rocks were carried out using modern as well as generally accepted classical methods of physical and chemical analyzes and physical and mechanical tests.

In this work, chemical analytical, X-ray diffraction, and electron microscopic analyzes were used.

The material composition of samples of basalt raw materials was determined by silicate rational chemical analysis using the accelerated method. The mineralogical composition of basalt samples was determined by X-ray phase analysis, which was carried out by the powder method on a Shimadzu LABX XRD-6100 X-ray diffractometer using CuKα radiation. Radiographs were taken with a step of 0.02, the tube current and voltage mode was 30 mA, 30 kV. Identification of mineral phases and analysis of the results was carried out using reference books and the generally accepted ICDD PDF-2 database [12-16].

The raster electron microscopic studies used in the work make it possible to study the elemental and phase compositions of minerals, morphological features and crystalline perfection of the particles composing them. The studies were carried out using scanning (SEM) CamScan-4 (Cambridge) and TESCAN VEGA IIXMU (Tescan) and transmission (TEM) JEM 2100 (JEOL, Japan), Tecnai G230ST TEM/STEM (FEI, Hillsboro, OR, USA) electron microscopy [16].

RESULTS AND DISCUSSION

To design the compositions of ceramic masses, kaolins from the Shomishkul deposit and basalts from the Berkurtau deposits were used as raw materials.

The results of determining the chemical composition of the used raw materials for ceramic masses are given in Table 1 and, accordingly, the component compositions of the test sample charges based on the developed recipe are given in Table 2.

Table 1

Chemical compositions of raw materials used

Name of raw material	Oxides content (weight %)								LOI, weight %
	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	

Shomishkul kaolin	66,34	16,61	0,86	1,75	0,70	2,03	3,10	1,20	7,12
Berkuttau Basalt	55,71	17,21	0,91	6,62	3,83	0,62	1,92	10,15	3,00
Tabakkum dune sand	79,24	5,36	0,30	1,32	4,56	1,78	1,25	1,25	3,97

Table 2

Compositions of experimental ceramic masses based on Shomishkul kaolin and Tabakkum dune sand using Berkuttau basalt

Name of masses	Components, weight %		
	Kaolin	Berkuttau basalt	Dune sand
KBS-1	50	30	20
KBS -2	50	25	25
KBS -3	50	20	30
KBS -4	55	30	15
KBS -5	55	25	20
KBS -6	55	20	25
KBS -7	60	15	25
KBS -8	60	20	20

The prepared raw material compositions (Table 2) were subjected to heat treatment in a silit furnace at a temperature of 950-1150 ° C with exposure at a maximum temperature of 15-20 minutes. As a result of high-temperature firing of experimental samples containing basalt rock, it promotes smooth formation at lower temperatures and increases the reactivity of the initial components - kaolin and dune sand. Thus, during the firing of the basalt-containing mass, mullite grains are formed, which leads to an increase in the density and strength of the sample. (Fig.1). It should be noted that the crystalline phase structure of nascent minerals is stabilized, and the sintering temperature of the ceramic mass decreases.

In addition, basalt promotes complete sintering of the resulting ceramic masses by increasing the content of the liquid phase between kaolin and clay minerals. As a result, kaolin and dune sand enter into a chemical reaction at lower temperatures, and a well-sintered ceramic mass acquires maximum density and strength.

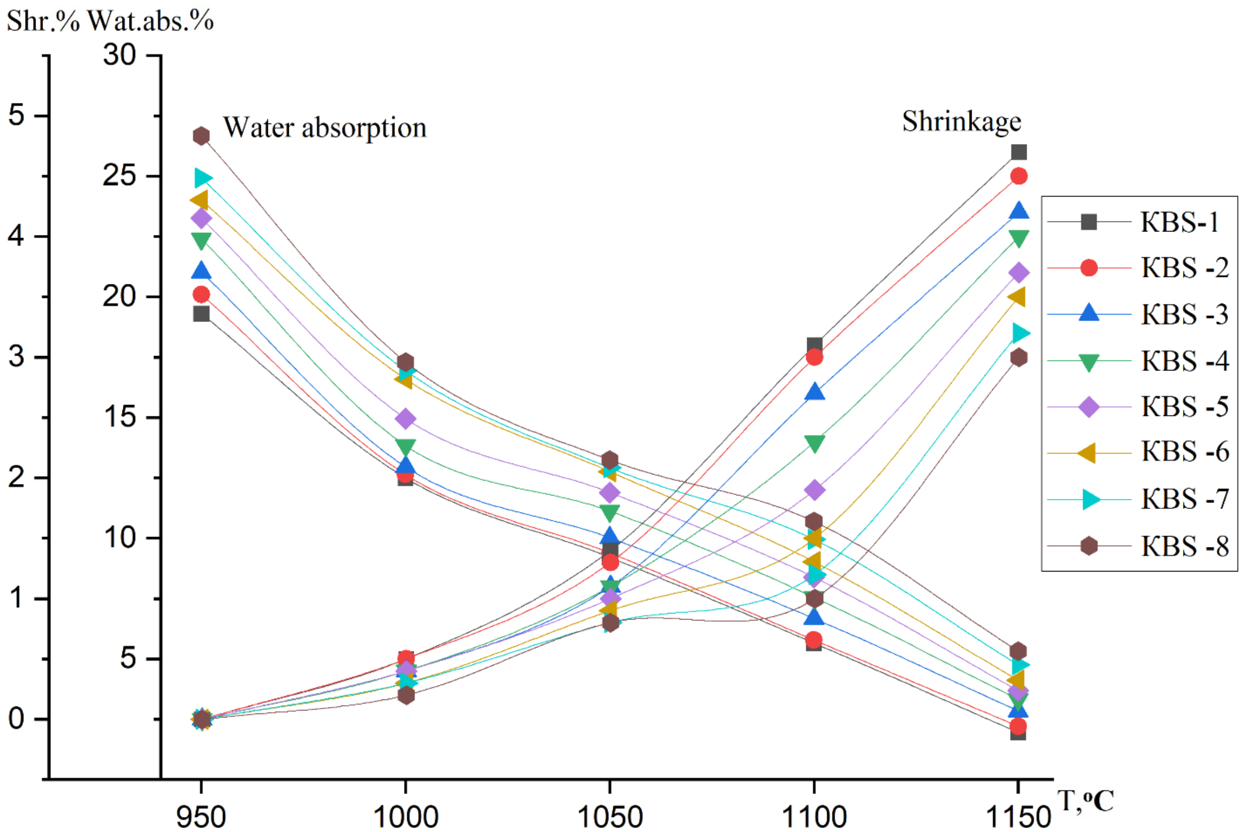


Fig.1. The influence of basalt on shrinkage and water absorption of ceramic mass samples depending on the firing temperature

Determination of water absorption and shrinkage values show (Fig. 1) that the addition of basalt significantly reduces the temperature of the beginning and end of melting of experimental samples of ceramic mass, however, a large amount of its addition leads to an increase in shrinkage, as a result of the formation of a large amount of the liquid phase of ceramic samples and their curvature.

As a result, the water absorption of ceramic samples sharply decreases, which does not meet the technological requirements. According to the requirements of GOST 13996-2019 [10, 11] and GOST 6141-91, water absorption for external facing ceramic slabs should be W = 2-9% and for internal ones 4-12%, and shrinkage of samples should not exceed 5%.

It should also be noted that very low shrinkage rates and high water absorption rates are signs of an insufficient degree of completion of the sintering process, which significantly affect the physical and technical characteristics of ceramic materials. Thus, when studying a number of series of ceramic prototypes, it was established that when using basalt from the Berkurttau deposit, the optimal content is an additive in an amount of 10 to 30 wt.%.

As a result of the studies carried out to study the basic properties of prototypes of ceramic masses, areas of satisfactorily sintering compositions were identified, which in their indicators were close to those established by the standard requirements of GOST 13996-2019 [10, 11].

Based on the results of standard laboratory tests, the optimal composition of the experimental ceramic mass, KBS-8, was selected, consisting of 60% kaolin, 20% basalt and 20% dune sand.

To study mineral formation in the optimal KBS-8 sample, X-ray phase analysis was used [7, 8], the results of which are presented in Fig. 2

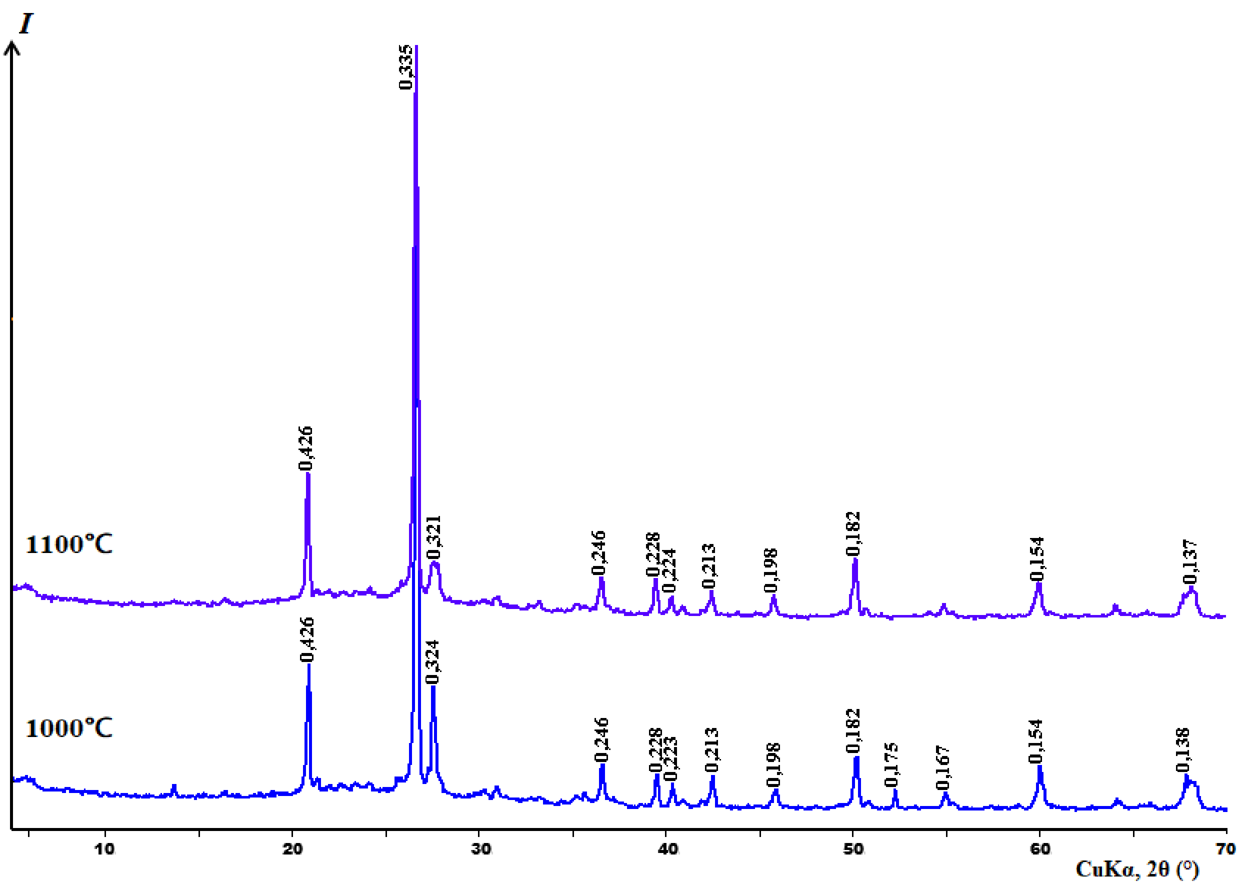
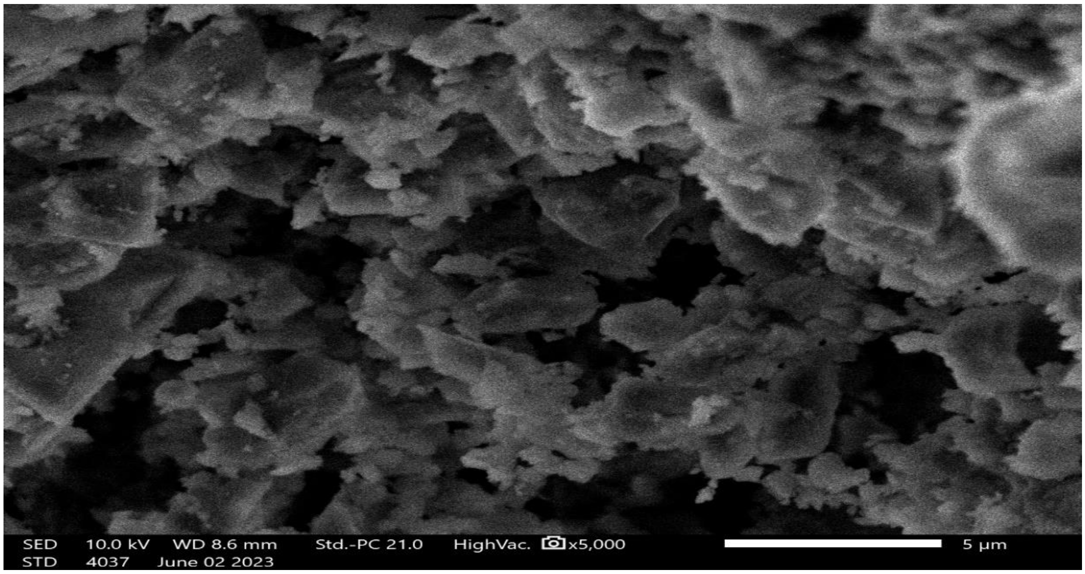


Fig.2. X-ray diffraction patterns of samples from the optimal mass KBP-8, fired at temperatures of 1000 and 1100°C

As can be seen from the X-ray diffraction pattern (Fig. 2), all fired samples of optimal composition contain intense lines of diffraction maxima related to minerals of the high-temperature form of quartz with interplanar distances: d = 0.335; 0.426; 0.167; 0.182; 0.165; 0.138; 0.182 nm, mullite with diffraction maxima: d=0.364 and 0.218 nm;

Electron microscopic analysis at magnification up to 50 μm shows various forms of closed pores, clear boundaries between the structure of the formed mullite fragments and also large quartz particles. (Fig.3).



Pic. 3. Electron microscopic image of the sample optimal composition of KBS-8 (scale - 1 cm:5 µm)

Based on the presence and quantity of minerals, as well as the firing temperature of the prototype from the KBS-8 mass at 1100°C, it is possible to ascertain the formation of the structure of the crystalline phases of the new formations of the ceramic shard, in particular quartz and mullite minerals, which impart the necessary strength qualities to the ceramic material [9].

CONCLUSION

Thus, the results of experimental studies of the compositions of ceramic slabs using Shomishkul kaolin, Berkuttau basalt and Tabakkum dune sand lead to stabilization of the structure of the crystalline phases of minerals and a decrease in the sintering temperature of test samples. It has been established that the tested components of new deposits can be used as raw materials in the development of mass compositions for the production of ceramic slabs.

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