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Alternative Source of Clay Raw Materials-Silt Deposits of Reservoirs for Production of Ceramic Materials

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Abstract
The possibility of obtaining a new alternative source of clay raw materials for the development of the composition of ceramic masses for construction purposes using clay-silt deposits of reservoirs with functional properties is considered. It has been established that ceramic masses based on a composition of silt deposits and kaolin waste can be used for the production of ceramic materials for construction purposes.

Keywords: ceramics, clay, silt deposits, kaolin, quartz, anorthite, mullite, vollastonite, melting point, fire shrinkage.

Introduction

Currently, due to the high rate of development of the construction industry, the construction materials industry in Uzbekistan has a great need for promising raw materials, particularly natural raw materials and secondary resources for the production of ceramic materials for construction purposes. It can be noted that wall-mounted ceramic materials are currently one of the most sought-after products. Therefore, the problem of expanding the raw materials base for large-scale construction materials is inextricably linked to the use of new non-traditional mineral and secondary resources.

In this regard, the purpose of this work is to study the suitability of the silty sediments of Uzbekistan's reservoirs and the kaolin waste generated during the extraction of brown coal for the design of new and in-demand ceramic masses in order to obtain ceramic materials for construction purposes. It should be noted that the use of silty sediments can reduce the consumption of traditional mineral resources by solving the country's economic and environmental problems (Khodjaev & Virovets, 2001; Nikitin, 1991).

Materials and Research Methods

For conducting experiments, samples of mineral-silt bottom sediments of the reservoir, kaolin waste of Uzbekistan, and experimental ceramic masses based on them were used as research objects.

The X-ray diffraction pattern was recorded on a Shimadzu diffractometer (Japan) in step-by-step scanning mode using Cu Kα radiation at angles 2θ0 with a shooting step of 0.05° and a current and voltage mode of 30 mA and 40 kV, respectively. When identifying the crystalline phases of minerals and discussing the results, we used standard reference books and the international database for powder X-ray analysis (Tolkachev, 1968; ASTM, 2005).

In order to conduct research on the development of compositions of ceramic masses based on silty deposits of a reservoir, presented from different places, the samples were pre-dried first in their natural form and then in a drying cabinet at a temperature of 100-1100C. Samples from reservoirs of air-dry state were crushed in a ball mill until complete passage through a sieve, the size of which is 1 mm. After that, kaolin waste was added to the mass in different quantities. The grinding of components based on the composition of silty sediments and kaolin waste was carried out in ball mills.

Then, the resulting mixtures based on this composition were moistened in order to achieve a normal molding moisture content of the mass. Next, laboratory samples in the form of cubes, bars, and tiles were prepared from these masses using plastic molding in metal molds. After drying, the crack-free samples were subjected to firing. The firing of the developed compositions of silty sediments–kaolin waste was carried out in laboratory electric muffle furnaces in the temperature range of 950–11000C with a step of 500C, and an exposure of 1 hour. The melting point of the samples from the experimental masses was determined by heating them and recording the temperature at the moment of falling of the cones.

Sintered samples were studied at various firing temperatures using classical testing methods and ceramic material manufacturing technologies (Vakalova et al., 2013).

Results and Their Discussion

The results of chemical analysis of the material compositions of a number of samples of silty deposits of the reservoir and kaolin waste from Uzbekistan are given in Table 1.

As can be seen from Table 1, the chemical composition of the studied samples is similar to that of ordinary low-melting clays in terms of the content of silicon, aluminum, iron, and alkaline and alkaline-earth oxides.

The chemical and mineralogical composition of the silty sediments of the reservoir mainly consists of montmorillonite minerals with hydro-mica.

Table 1: Chemical composition of the studied silty sediments and kaolin waste

Naming of raw materials	Mass content of components, %											
	SiO_2	Fe_2O_3	FeO	TiO_2	Al_2O_3	CaO	MgO	K_2O	Na_2O	SO_3	P_2O_5	losses during calcination
1	50,14	3,77	0,86	0,49	12,28	9,70	2,01	2,40	1,64	–	0,24	12,45
2	47,52	4,26	0,79	0,45	13,11	11,87	2,39	2,69	1,13	–	0,25	12,18
3	45,85	5,94	1,05	0,60	13,88	12,15	2,83	2,62	0,81	–	0,31	13,64
Average	47,83	4,65	0,90	0,50	13,09	11,25	2,40	2,58	1,18	–	0,27	12,74
Kaolin waste	67,49	0,75	0,43	0,50	21,36	0,28	0,22	–	0,75	0,16	0,01	7,84

The carbonate content of the silty sediments of this reservoir is high, as the average content of calcium and magnesium oxides is 11.25 and 2.40 wt.%, respectively. Based on the chemical and mineralogical composition, the silty sediments of the reservoir are classified as silt loam clays (Sabirov et al., 2018). The mineralogical composition of the reservoir's silty sediments, as determined by X-ray phase analysis, consists of clay minerals (kaolinite and Illite), stony minerals such as quartz, calcite, and feldspar, as well as small amounts of hematite (Fig. 1).

It should be noted that in the mineralogical composition of the silty deposits of the reservoir, the content of kaolinite ranges from 21.0 - 22.5%; Illite -18.6 - 20.3; quartz -21.9 - 25.7; albite -15.1 - 17.3; calcite -15.4 - 18.6; hematite -4.0 - 2.2 (Guzman, 2004; Mirkin, 1964).

The results of scanning electron microscopic analysis of reservoir samples (Figure 2) also confirms the data of X-ray phase analysis that the mineralogical composition of the reservoir sample consists mainly of montmorillonite minerals with corresponding admixtures of carbonates, kaolinite, cristobalite, iron hydroxides and organic compounds.

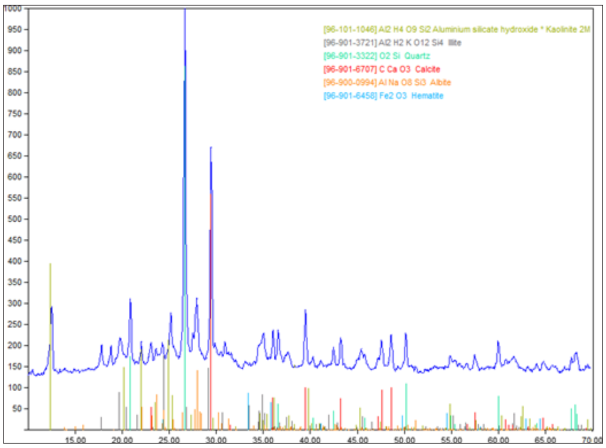


Figure 1: X-ray image of the silty deposits in the reservoir of Uzbekistan

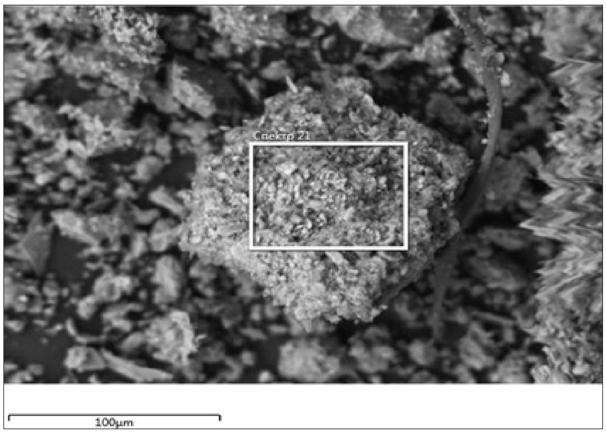


Figure 2: SEM image of the silty deposits in the reservoir

It should be noted that the suitability of raw materials, in particular, the silty deposits of reservoirs, as a clay raw material for ceramic masses is determined by their technological and physical-mechanical properties.

From Fig.3 it is seen that the presence of cations Ca, Fe, Na, Mg, Al, Si and K in the spectra confirm the polymineralty of the silty deposits of the reservoir. The results of determining the ceramic and technological properties of a number of experimental samples of the reservoir's silty sediments are presented in Table 3.

Based on the experimental study, it was found that the mineral silty bottom sediments of the reservoir have physical, mechanical, and technological properties similar to those of traditional low-melting clays (Kovba &Trunov, 1976; Tairov et al., 2023).

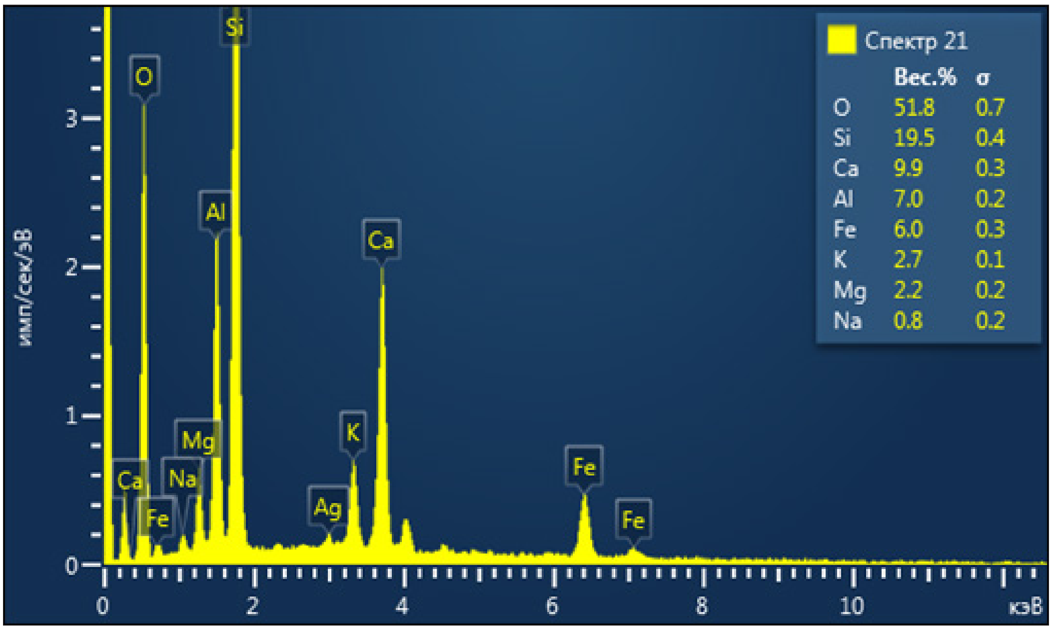


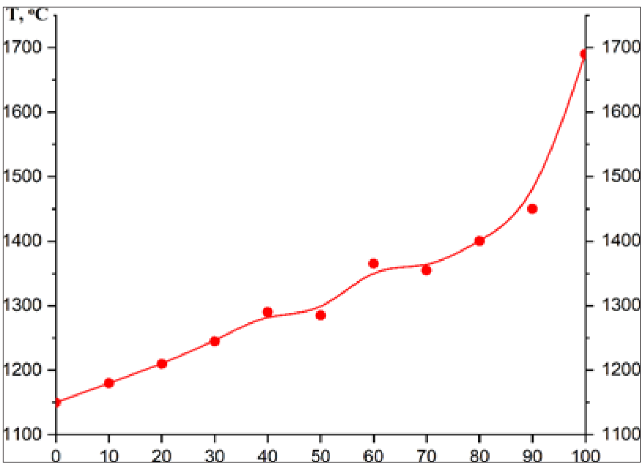
Figure 3: X-ray fluorescence spectrum of a silty sediment sample from a reservoir

Table 2: Ceramic-technological properties of silty deposits reservoir

Name of the sample	Forming moisture content, %	Plasticity number (P.n.)	Air linear shrinkage, %	Sensitivity coefficient for drying using the Chizhsky method	Compressive strength, MPa	Volume weight, kg/m^3
1	22,24	7,0	4,57	Более 180 с	2,72	1657
2	24,37	9,0	4,94	Более 180 с	2,66	1652
3	23,11	8,0	4,43	Более 180 с	2,37	1644

Laboratory samples of ceramic masses based on the composition of silty sediments – kaolin waste from 5 samples were made in the concentration range of 5–10 wt.% of the initial components to determine the melting point.

The results of the obtained experimental data on determining the melting points of the initial components and experimental samples based on the silty sediments of the reservoir are presented in Fig. 4.



Muddy clay by weight. % kaolin waste

Figure 4: Melting temperature curve of a silty sediment–kaolin waste composition

As a result of the study of the melting point of the developed compositions, it was found that the melting point of the samples increases with an increase in the content of kaolin waste. Figure 4 shows that there is a significant increase in the melting point of the samples in the temperature range of 1400-1450°C and a mass content of kaolin of 80.0-90.0%. (Andrianov et al., 2012; Andrianov, 2005).

The developed compositions of silty sediments and kaolin waste can be classified as low-temperature sintering ceramic masses. It should be noted that compositions with a kaolin waste content of more than 40% have medium- and high-temperature sintering properties.

The formation of refractory ceramic masses with a melting point of 1400-1580 0C is observed in samples with a kaolin waste content of 50-90% by weight.

The results of determining the main physical and mechanical characteristics, in particular, changes in water absorption, density, and mechanical compressive strength of the experimental samples of the double composition of silty sediments and kaolin waste, are shown in Figure 5 (Kuryazov et al., 2021).

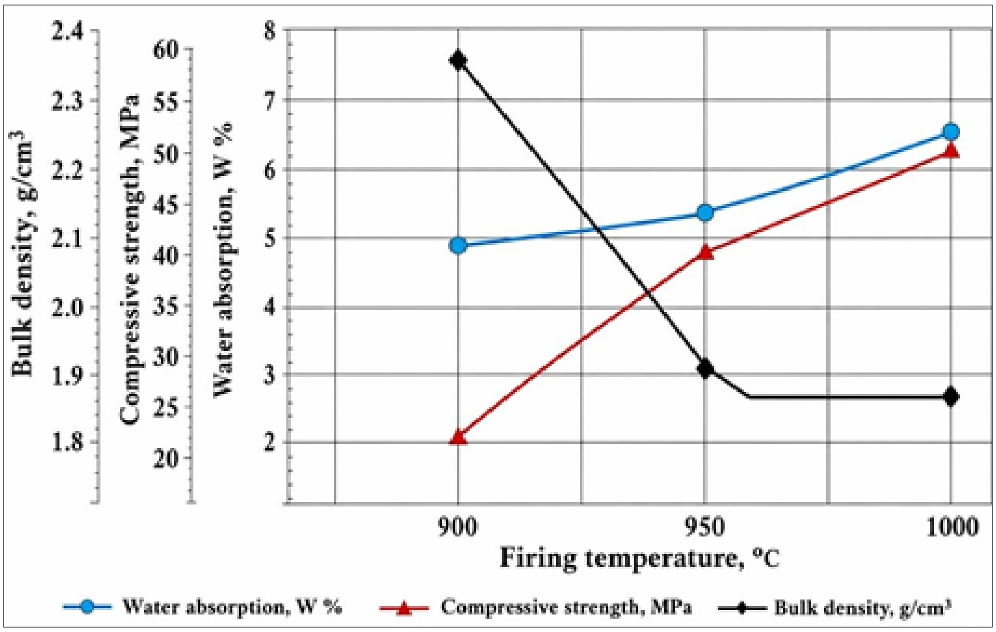


Figure 5: Changes in the physical and mechanical properties of samples containing 80 wt. % silty sediments + 20 wt. % kaolin waste. - water absorption, %; - density, g/cm3; - compressive strength, MPa

It should be noted that the studied ceramic masses based on the silty deposits of the reservoir in the form of double compositions with kaolin waste are classified as low-melting inorganic materials in terms of sinterability.

As a result of the conducted experiments, it was found that linear and volumetric changes occur in the samples of silty deposits and kaolin waste during high-temperature processing. This results in intensive shrinkage, reduced water absorption, and increased mechanical strength in compression. Therefore, in order to determine the optimal compositions of ceramic masses for construction purposes, particularly in the production of ceramic bricks and blocks based on silty deposits from reservoirs using kaolin waste, the experimental samples were fired at a temperature of 980-1000°C.

The results of heat treatment at this temperature showed that the samples containing kaolin waste in amounts of 20 and 30 wt.% were the most sintered. It should be noted that as the heating temperature increases, the fire shrinkage of the test samples increases. However, when more than 20 wt.% of kaolin waste is added to the mass, the physical, mechanical, and technological properties of the test samples deteriorate. Therefore, it was determined that adding up to 30 wt.% of kaolin waste to the mixture of the samples does not affect their properties. % improves their physical, mechanical, and technological properties (Pavlova et al., 2020; Dyatlova & Biryuk, 2006).

Conclusion Thus, the silty deposits of reservoirs are a new alternative source of clay raw materials that meet all the technological requirements for clay raw materials for developing an effective composition of masses and technology for the production of ceramic wall materials.

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