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MANUFACURING OF THE KYSHTYRLINSKY CLAY-BASED CERAMIC STRUCTURES OF HIGH QUALITY

SUMMARY. This paper considers the technique for manufacturing coarse structural ceramics from the Kyshtyrlinsky montmorillonite clay. To influence the material structure formation, the modifying carbon- and silica-containing additives, specifically, the Kamyshlovsky diatomite and artificially ground graphite, are added. The properties of the used raw materials and the detailed experimental technique are presented. The basic properties of the ceramic body produced from the modified three-component mixture are determined. To analyze the microstructure, the electron microscopy data are given. It is stated that the use of the additives results in a synergistic effect improving the structure quality. The traditional technology of producing coarse structural ceramics involves the use of the low-melting clay raw materials combined with the thinning agents and combustible additives, which does not always enable high physical, mechanical, and service properties to be obtained. The high functionality of diatomite and graphite is implemented in the function of the center forming multi-component composition which covers most of the technology requirements for ceramic materials, regardless of the production origin and mineral composition of the clay material. The complex additive usage facilitates producing high-strength ceramics from local clay minerals at the industrial burning points. The scientific and technological novelty of this research involves expanding the raw material base for the coarse structural ceramics and using the synergistic effect of the additives to improve the material quality.

KEY WORDS. Structural ceramics, microscopy, sintering, graphite.

The traditional technique for producing the coarse structural ceramics involves the usage of low-melting clay raw materials; the requirements for them are given in documentary standards [1]. Various fluxing additives are often added to the basic raw materials [2], [3]. It is caused by the ability to produce the sintered ceramic body from such raw materials at relatively low burning points (950-1,080 °C). The increase in the maximum temperature results in the considerable increase in power consumption and in the probability of over-burning and fragmentary surface vitrification. Besides, it is extremely difficult to distribute the low additive dosage throughout the whole batch volume at the existing techniques for the clay mixture preparation.

In some cases, enterprises (e.g., ZAO VZKSM – Vinzili Ceramic and Wall Materials Factory) have to use local high-melting raw materials, which make a technological process more complicated and degrade the ceramic body quality in terms of the incomplete sintering process. Besides, most of the quality improvement techniques involve the increase in cost (the use of the imported low-melting clay, fluxing additives, etc.) [4], [5]. Therefore, the matter of the ceramics quality improvement and the minimum increase in expenses is important, especially for the enterprise that provides the regional construction materials market with the bulk of coarse ceramics. The development of special additives and techniques provides fundamentally new opportunities for the strength synthesis.

The essence of the technological concept is to modify the raw mixture by the silica- and carbon-containing additives. In this case, the diatomite from the Kamyshlovsky deposit (the Sverdlovsk Region) and artificial graphite ground according to TU (Technical Specifications) 1916-109-71-2000, with the particle size of 0.5-3 mm, are used. The basic clay raw material is the clay from the Kyshtyrlinsky deposit, but to estimate the potential modification of another raw material and to make the experiment valid, the clays from the Uvatsky, Voroninsky-II, and Omutinsky deposits are also used. The chemical composition of the components, known from the previous chemical analyses and published data [6], is presented in Table 1.

The purpose of the paper is to improve the physical and mechanical properties of the structural ceramics by adding diatomite and graphite to the batch. While studying, the diatomite effect is determined in the wide range of its dosage, from 0 to 30%, the graphite content is assumed to be 4% by weight according to the previous studies [7].

Table 1

The chemical composition of the raw material in use

Material	Content, %						
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Other r.s.
Omutinsky clay	62.78-64.72	14-15.36	4.24-4.56	3.37-4.32	1.65-1.70	0.06	9-9.04
Kyshtyrlinsky clay	55.30-76.70	15.58-18.6	7.76-8.80	1.37-1.77	1.62-1.92	1.05-2.01	6.40-7.64
Voroninsky clay	71.43	12.56	5.1	1.19	1.12	-	7.71
Uvatsky clay	73.25	11.35	3.85	1.31	1.34	-	3.40
Kamyshlovsky diatomite	72.12	7.7	3.38	-	-	1.25	11.29

The research procedure involves the following:

— preparing the ceramic batch by dry mixing at the molding-moisture content of 15%;

— molding the cylindrical specimens, 50 mm in diameter and in height, at the molding pressure of 25 MPa;

— drying in the laboratory oven at 105 °C;

— burning in the laboratory electric furnace at the holding temperature of 1,000 °C.

The density, water absorption, and compressive strength of the finished products are determined. Fig. 1 and 2 present the changes in the compressive strength and density index of the burnt ceramics with diatomite in the doses from 0 to 30% having been added.

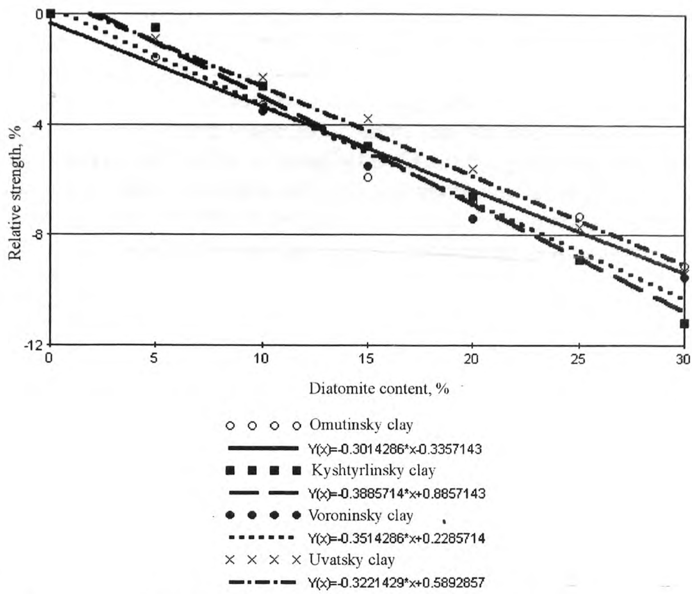

Fig. 1. The dependence of the burnt ceramics compressive strength on the diatomite content

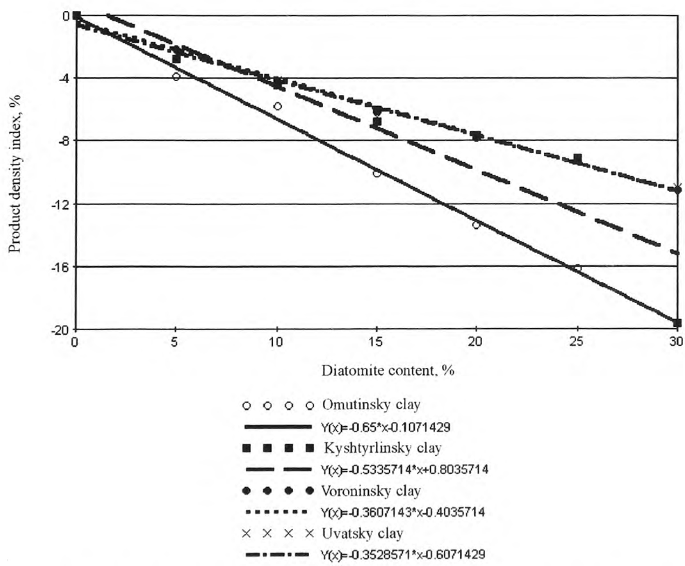

Fig. 2. The dependence of the product density index on the diatomite content

This dependence demonstrates that the increase of the diatomite content in the raw mixture results in the product strength reduction (on average, by 8%) for the montmorillonite and montmorillonite-kaolin clays. The change in the strength reduction is explained by intensifying the processes of the new aluminosilicate phase formation, namely, diatomite and graphite intensify the mullite- and sillimanite-formation, as mullite ($3Al_2O_3$ *$2SiO_2$) and sillimanite (Al_2O_3 *SiO_2) are basic minerals, hardening the burnt ceramic body [7], [8]. The previous X-ray structural analysis confirms the occurrence of these minerals [9]. Adding chemically active silica contained in diatomite to the mixture results in the increase in the content of sillimanite, with the lower strength than that of mullite. Besides, acting as a nonplastic material, the diatomite decreases simultaneously the strength and density of the products due to the closed porosity.

In Fig. 3 and 4, the micrographs of the burnt ceramic body are presented, specifically, its additive-free composition and its composition with graphite and diatomite by weight. The analysis is carried out by the electronic scanning microscopy using the *JEOL* equipment (Japan).

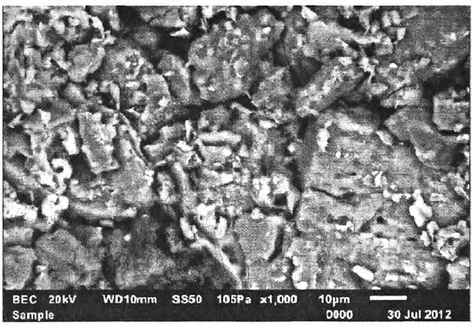

Fig. 3 The structure of the additive-free ceramic body, 1,000 magnification.

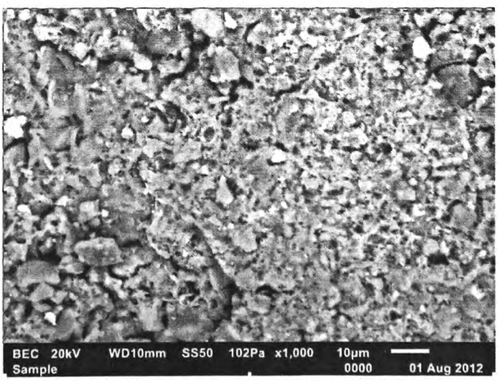

Fig. 4. The structure of the modified ceramic body, 1,000 magnification.

The micrographs demonstrate the distinct crystal complexes forming a dense skeleton and micropores, where the needles of the primary mullite are visible. Such changes in structure occur since graphite acts as a complex modifying additive raising the temperature inside the ceramic body when being burnt and fundamentally changing the gas medium within the product; that enables the mullite-formation to occur at lower temperature of the brick burning [10]. The fuller sintering of the mixture components due to adding the diatomite, a chemically active component, is observed. As compared to the additive-free composition, the denser structure containing fewer microdefects and having the prevailing strength is obvious.

Conclusion

1. The technological efficiency of the mineral components in the ceramic mixture is predetermined by their functionality, which depends on their nature, composition, and mechanism of action. Due to the high functionality of diatomite and graphite, they act as some center where the multi-component compounds are formed, and satisfy the most needs of the ceramic material production, regardless of the origin and the mineralogical composition of the clay raw material.

2. Due to the synergetic effect caused by the combined addition of diatomite and graphite to the raw mixture, the quality of the burnt product structure is improved, since the mullite and sillimanite crystals are formed, and the quantity of the glass rim as a binding agent for crystal complexes increases. It enables the high-strength ceramics to be produced with local clay materials used, at the industrial burning points.

3. The development of special complex additives and modern production technique provides fundamentally new opportunities for producing the high-quality ceramic structures involving the clay material which does not meet the requirements of documentary standards into the technological process [1]. Such a non-conventional approach makes it possible to expand the raw material base for the coarse structural ceramics, which is definitely a scientific and technological novelty.

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