Kyshtyrlinsk deposit clay properties research

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Abstract. The paper is devoted to study technological properties of low-melting clay. Research methods of clay properties that affect the technology of ceramic brick production are presented. The clay sample under study is an acid clay of montmorillonite mineral composition, medium plastic, with a low content of coarse inclusions and refers to low-disperse raw materials. A clay sample contains a low content of water-soluble salts, a low content of carbonate inclusions, and a low content (less than 1%) of coarse-grained inclusions. The clay is medium-drying, medium-sensitive to drying, non-sintering; after firing, it has high mechanical strength. Based on this clay, it is possible to produce common and face bricks with a strength of more than 10 MPa when using the plastic method of molding and firing in the range of 850–1050°C. Obtaining clinker brick requires refinement of the production technology by introducing sintering additives, since at this stage of project products are obtained with lower strength and high water absorption.

1 Introduction

Red-burning fusible clays are everywhere. As a rule, such clays are most often used in the production of ceramic bricks. Researching the clay properties, one can determine the fields of its application [1–5]. The mineral composition of fusible clays is very complex [6–8]. The fusible clays of the Ural region, as a rule, in terms of mineral composition are montmorillonite with kaolinite, muscovite, illite and others. Clays of montmorillonite mineral composition usually have high ductility but are difficult to withstand the drying process; they tend to crack during drying. Drying such clays should be done slowly. In addition, in order to improve the drying process of such clays, materials are added to the composition of the ceramic brick in the form of ash, sawdust, sand, some types of metallurgical slag, low-plastic, thin clay, and others. Montmorillonite clays, especially plastic ones, are subject to cracking during firing to explosive destruction. Products containing montmorillonite clay in the mass should be fired slowly. Clays of kaolinite mineral composition have good ductility and low sensitivity to drying. These clays withstand high-speed firing modes easily.

Ceramic brick is a wall building material produced by molding and subsequent firing of products from a mixture of clay and a shrink-reducing material. The raw materials are fusible clays. Clays are used for brick production, in which the total SiO2 content is not more than 85%, and free SiO2 is not more than 60%. The content of Fe2O3 in clay should be no more

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than 14%, the plasticity number should be at least 7. Ceramic bricks are produced in a plastic and semi-dry way. Ceramic products are fired in the temperature range of 850–1100°C.

2 Experimental procedure

The chemical composition of the materials is determined according to [9–18]. The content of free SiO2 in clay was determined according to [19].

Differential thermal analysis was performed by derivatograph (MOM). Heating was carried out in a platinum crucible up to 1000°C with a speed of 10° per min. Al2O3 was used as a reference.

Plasticity was tested in accordance with [19]. The plasticity of clay tempered with water is its ability to deform under the influence of a load without breaking the continuity (formation of cracks), take any shape and save it after the removal of the load. The plasticity of clays depends on their disperse and mineral composition. The more dispersed the clay, the higher its plasticity. In ceramic technology, there are many methods for estimation of the plasticity of clays and ceramic masses. All these methods are divided into 2 groups: direct and indirect. Indirect methods cannot simultaneously evaluate the plasticity and molding ability of clays and plastic ceramic masses. As an example of the method of indirect plasticity estimation, the Vasil'ev method proposed by [19] is used. When determining clay plasticity using the Vasil'ev method, the plasticity number P is determined, which is the difference between the relative humidity of the clay at the lower yield strength and the relative humidity of the same clay determined at the plastic limit [20].

The sensitivity of clays to drying was determined by the method of Z. A. Nosova. The sensitivity of clays to drying is their ability or tendency to crack during drying. The cause of cracks is the different shrinkage over the cross section and on the surface of the product. Shrinkage cannot occur evenly for the entire product, as humidity in the surface and in its central zones varies during the drying process. The nonuniformity of shrinkage causes internal local stresses in the material, which can exceed its mechanical strength and cause deformation of the raw material and the formation of cracks. It is the nonuniformity of shrinkage and internal local stresses caused by shrinkage that cause cracking and defects during drying. The coefficient of sensitivity to drying is the ratio of the volumetric shrinkage during drying to the real porosity of the material in the air-dry state. The smaller this coefficient, i.e. the less clay shrinkage during drying, the easier and safer the drying of products. Clays highly sensitive to drying have coefficient of sensitivity of more 1.5; medium-sensitive clays have this index of 1–1.5; insensitive clays have coefficient of sensitivity less than 1.

The ratio of materials to sintering is determined according to [19]. To determine the sintering ability of clay from the mass of optimal molding moisture content (W = 18%), cubes of size 50×50×50 mm were formed. Samples are dried and fired at a temperature of 800–1050°C.

3 Results and discussion

To identify the mineral composition of the studied brown clay sample, DTA and TG curves were taken into account. It is known, that if fusible clay, when heated in the temperature range of 20–200°C, has a mass loss during calcination of 2% or more, then in this clay montmorillonite is presented. In this clay, the mass loss in temperature range of 20–200°C was 4.4%. The presence of an endothermic effect at 538°C and an exothermic effect at 885°C also shows that montmorillonite is the main mineral in brown clay. A small endothermic effect at a temperature of 568°C indicates the presence in the clay of an insignificant amount (up to 3%) of the kaolinite mineral.

Thus, the investigated clay is of montmorillonite mineral composition. It should have enough plasticity and medium sensitivity to drying.

The chemical composition of clay in its natural state and in terms of calcined matter is given in Table 1.

Clay is acidic one with an Al2O3 content in the calcined state of 11.10%, a high content of coloring oxides of 5.5% (TiO2 + Fe2O3 > 3%), and a low content of carbonate inclusions of 1.13%. In accordance with the diagram of A. Augustinnik in relation to the moles of SiO2 / Al2O3 = 0.084 and the content of smoothers in mol.% (CaO + MgO + Na2O + K2O + Fe2O3) = 0.114, the clay under study may be suitable to produce clinker and building bricks.

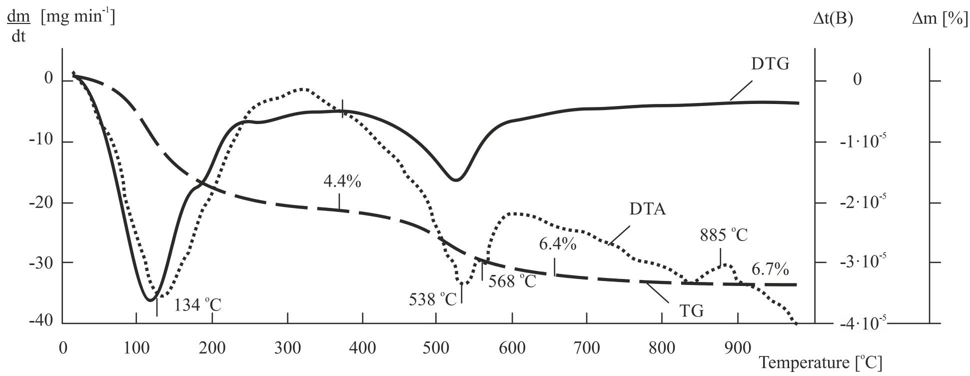

Fig. 1. Kyshtyrlinsk clay derivatogram.

Table 1. The chemical composition of clay.

Oxide	SiO_2	Al_2O_3	CaO	Fe_2O_3	MgO	Na_2O	K_2O	TiO_2	LOI
Content in natural clay (%)	72.55	10.35	1.05	4.50	1.02	1.00	1.72	0.62	6.75
Content in calcined matter (%)	77.83	11.10	1.13	4.83	1.09	1.07	1.85	0.67	–

The content of water-soluble salts in brown clay is 1 mg·eq per 100 g of clay, which makes it possible to attribute this raw material to clays with low (from 1 to 5 mg·eq per 100 g of clay) content of water-soluble salts.

Brown clay contains 37% free quartz and belongs to clays with a high content of free quartz (> 25%). The predominant size of quartz particles is from 0.5 to 0.063 mm.

Clay refers to raw materials with a low content of coarse inclusions of more than 0.5 mm and is 0.95%. In this case, the maximum particle size of inclusions does not exceed 1 mm. In terms of material composition, inclusions are represented by quartz and negligible inclusions of silicon.

The distribution of fine fractions in clay is presented in Table 2.

Table 2. The distribution of fine fractions in clay.

Particle size (mm)	> 0.06	0.06–0.01	0.01–0.005	0.005-0.001	< 0.001
Fraction content (%)	34.38	11.78	3.24	11.36	39.24

According to the content of particles with a size of less than 10 microns (53.84%), clay is a low-dispersed raw material.

The plasticity of brown clay according to the method of Vasil'ev is 16.8. Clay moisture at the lower yield strength is 28.0%, humidity at the limit of rolling is 11.2%. The number of plasticity of brown clay P = 28.0 – 11.2 = 16.8; which makes it possible to classify brown clay as a medium plastic raw material.

Clay refers to medium-sensitive to drying (coefficient of sensitivity to drying is of 1.34 according to the method of Z. A. Nosova). In terms of air shrinkage (7.9%) this clay is average drying one.

The ratio of clay to sintering was tested after firing clay samples in the range of 800–1050°C. The total shrinkage of the samples decreases from 8 to 9%, porosity decreases from 26 to 19%, the apparent density increases from 1990 to 2060 kg·m-3, compression strength increases from 8 to 24 MPa.

Table 3. Post-firing properties of the samples.

Firing temperature (°C)	**Shrinkage (%)**		**Water absorption (%)**	**Open porosity (%)**	**Apparent density ($kg \cdot m^{-3}$)**	**Compressive strength (MPa)**
	total	**fire**				
800	8.1	0.2	13.2	26.3	1990	8.1
850	8.2	0.3	12.0	24.0	2000	13.2
900	8.3	0.4	10.6	21.3	2010	16.5
950	8.6	0.7	10.5	21.3	2030	18.4
1000	8.9	1.0	9.8	20.0	2040	18.8
1050	9.2	1.3	9.2	19.3	2060	24.3

At all firing temperatures, a water absorption value of less than 5% has not been achieved, which indicates that the clay under study is a non-sintering clay raw material.

4 Conclusion

The sample of clay under study is clay of montmorillonite mineral composition, medium plastic, with a low content of coarse inclusions and refers to low-dispersed raw materials. A clay sample contains a low content of water-soluble salts, a low content of carbonate inclusions, and a low content (less than 1%) of coarse-dispersed inclusions. The clay is medium-drying, medium-sensitive to drying, non-sintering; after firing, it has high mechanical strength. Based on this clay, it is possible to produce common and face bricks with a strength of more than 10 MPa when using the plastic molding and firing method in the range of 850–1050°C. Making clinker bricks is difficult due to the fact that the minimum compressive strength for clinker bricks according to [21] is at least 30 MPa and water absorption of less than 6%.

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