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# Il'insky diatomite in building ceramics production

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**Abstract.** The possibility of using diatomite rocks of the Il'insky deposit in the ceramic brick production has been considered. The chemical and mineral composition of diatomite was determined, and its molding properties were studied. The effect of temperature on the degree of sintering of diatomite was established. The technology of brick production was developed. The main stages of brick production by the method of semi-dry molding are determined. The recommended molding parameters (moisture content and specific pressure of pressing) are proposed. The diatomite properties have been studied and the technology of producing bricks by the method of semi-dry forming has been developed. The samples of ceramic bricks of the grade M100 up to M400 with the medium density class – 1.2 have thermal characteristics, relating to the group of effective products with the coefficient of thermal conductivity of the masonry in the dry state in the range of 0.24 to 0.36 W/(m·°C).

## 1. Introduction

The aim of this work is to study the complex properties of the Il'insky diatomite for the production of building ceramics. Diatomite building brick in comparison with clay has a number of advantages, namely, this brick is a lighter, less sound and heat conductive. Accordingly, buildings and structures made of such materials will sustain a lower structural load and will be more efficient in thermal conductivity.

According to [1], the deposit is confined to the deposits of the Irbit Eocene formation. Estimation of Il'insky diatomite stocks as raw material for construction materials production is given. The useful thickness capacity of diatomite is 14.3–29.7 m (average value is 18.9 m), the thickness of uncovering is 1.0–10.0 m. Diatomite is characterized as low-dispersed where clayey particles content less than 0.001 mm is 15–39.1%, as medium-plastic with low and medium content of coarse-grained inclusions – 0.1–6.9% where small and medium inclusions are predominated. It is shown that diatomite can be used as a mineral additive in the production of dry building mixtures [2-4]. The reserves are counted in the amount of 10'449'000 m<sup>3</sup> in categories C1 + C2 for open-pit mining. Opal-cristobalite rocks (triplet, diatomite) of the Urals can be considered as a multi-purpose raw material – to produce the heat-insulating and construction materials (brick, shell, cellular glass) [5-23], various fillers, catalyst carriers, and filters for purifying and discoloring sugar syrups, vegetable oils, clarification of various petroleum products, drying liquids and gases etc. [24-26].

Hence, an actual problem is to study the possibility of using the diatomite of Il'insky deposit with respect to the production of ceramic bricks, as well as the its production technology development.



## 2. Results and discussion

To assess the suitability of diatomite as a raw material to produce the ceramic brick according to [27], its properties were investigated in accordance with [28].

The chemical composition of the diatomite of the Il'insky deposit is presented in table 1. According to the chemical analysis the diatomite refers to acidic raw materials with a high content of coloring oxides.

**Table 1.** Chemical composition of diatomite of the Il'insky deposit.

Material	Weight content, %								
	LOI	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO	Na <sub>2</sub> O	K <sub>2</sub> O	TiO <sub>2</sub>
Dry matter	5.77–	72.67–	9.44–	4.01–	0.15–	1.15–	0.30–	1.25–	0.55–
	7.02	75.23	10.87	6.33	0.99	1.22	0.34	1.29	0.65
Calcined matter	–	77.41–	10.21–	4.31–	0.16–	1.25–	0.33–	1.35–	0.61–
		81.11	11.58	6.74	1.11	1.32	0.35	1.39	0.71

The granulometric composition of diatomite is presented in table 2. This analysis was carried out in accordance with [29]. Depending on the content of finely distributed fractions, the diatomite refers to medium-dispersed raw with a particle content of less than 10 μm of 81.63% by weight.

**Table 2.** Granulometric composition of diatomite of the Il'insky deposit.

Fraction size, mm	Particle content, %
0.25–0.06	8.26
0.06–0.01	10.11
0.01–0.005	4.08
0.005–0.002	57.14
less than 0.001	20.41

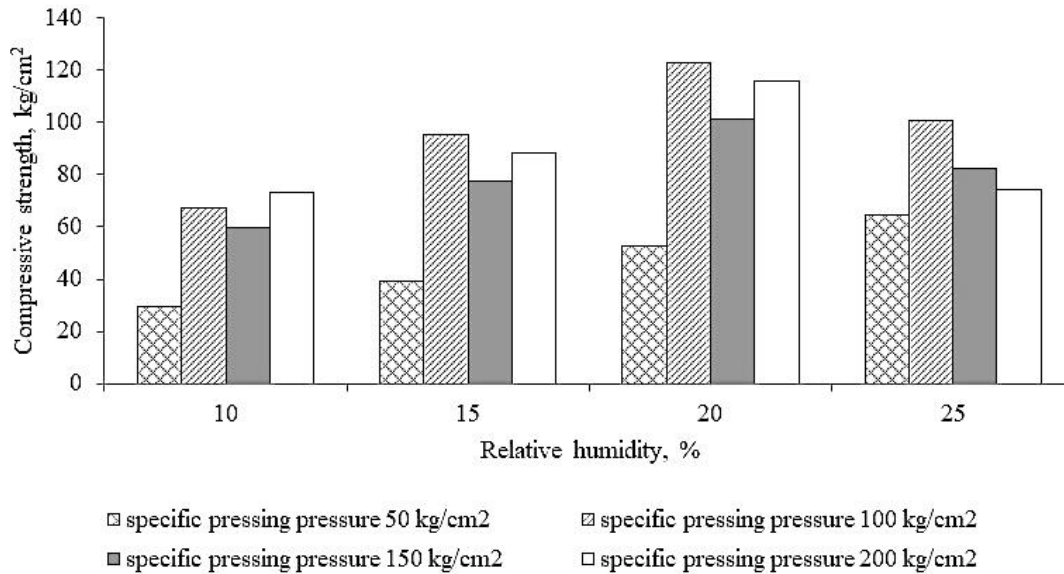
The mineral composition of the diatomite raw material was determined by differential thermal analysis and X-ray test. It is found that the diatomite of the Il'insky deposit is a polymineralic raw material with a main component content – amorphous SiO<sub>2</sub> of 70–77 wt. %, clay minerals (montmorillonite glandular clay), 9–14 wt. % and quartz sand 3–4 wt. %. The quarry humidity of diatomite is 41.1–42.7%.

The plasticity number of diatomite of Il'insky deposit is 16 at relative humidity corresponding to a yield strength of 46% and a rolling limit of 27%. Hence, diatomite refers to the midplastic raw material.

To determine the parameters of brick forming, samples were prepared as follows: the diatomite raw material was ground to a fraction of 3 mm and mixed with water to a moisture content of 10, 15, 20 and 25%. Samples were made with a height and diameter of 50 mm on a laboratory hydraulic press in a metal mold at a specific pressing pressure of 50, 100, 150 and 200 kg/cm<sup>2</sup>. The compressed samples were dried at room temperature (22 ± 5) °C for 5–6 hours and dried in a laboratory drying oven at (100 ± 5) °C to a constant weight. The dry strength of the dried samples was determined. The results are shown in figure 1.

According to figure 1 at a forming humidity of 15, 20, 25% the maximum strength is obtained by samples formed at a specific pressure of 100 kg/cm<sup>2</sup>. Increasing the pressing pressure from 100 to 200

kg/cm<sup>2</sup> leads to a decrease in the strength of the raw material, respectively, the use of pressing pressure above 100 kg/cm<sup>2</sup> is no expediency. The natural moisture content of diatomite is 40–47%.



**Figure 1.** Strength of samples depending on humidity and specific pressing pressure.

In the process of diatomite products production by a semi-dry method of forming, it is necessary to provide drying of the material. It should be taken into account that with further processing of dried diatomite, a large amount of dust will occur, and also the lower the humidity after drying, the higher the drying costs.

Based on these considerations in the technology of diatomite brick production, it is necessary to dry the diatomite to humidity, which will ensure high strength of the raw material and at the same time with the lowest costs for drying. Products forming is recommended to carry out at a pressure providing high strength. Thus, the recommended pressing pressure is 100 kg/cm<sup>2</sup> and the humidity is 20%.

Then the dried samples were fired at 800 °C. The properties of the samples after firing are presented in table 3.

**Table 3.** Effect of forming and firing conditions on the samples properties.

Forming conditions		Properties after heat treatment			
humidity, %	pressing pressure, kg/cm <sup>2</sup>	water absorption, %	open porosity, %	average density, g/cm <sup>3</sup>	compressive strength, kg/cm <sup>2</sup>
20	50	34	48	1.14	138
15	100	31	52	1.33	177
20	100	27	43	1.34	264

It can be seen from the table 3 that the maximum strength after firing is also exhibited by samples formed at a humidity of 20% and a pressing pressure of 100 kg/cm<sup>2</sup>.

To determine the firing temperature of products from diatomite the brick samples were made at a humidity of 20% and a specific pressing pressure of 100 kg/cm<sup>2</sup>. Samples were fired in the temperature range 900–1200 °C in 50°. The samples properties after firing are given in table 4.

**Table 4.** Samples properties as a function of the firing temperature.

Temperature, °C	Water absorption, %	Average density, g/cm <sup>3</sup>	Compressing strength, kg/cm <sup>2</sup>	Coefficient of frost resistance
900	39.3	1.17	156	0.98
950	36.7	1.20	229	0.93
1000	35.1	1.09	211	0.93
1050	29.0	1.10	372	0.96
1100	22.6	1.11	469	0.97
1150	12.8	1.12	523	0.83
1200	11.0	1.12	492	0.80

The strength of the samples increases with an increase in the firing temperature from 156 to 492 kg/cm<sup>2</sup>, the water absorption decreases from 39 to 11%, the average density at firing in the temperature range 900–950 °C increases from 1.17 to 1.20 g/cm<sup>3</sup>, with further increase the temperature of firing up to 1000 °C is reduced to 1.09 g/cm<sup>3</sup>. This behavior is typical for diatomite rocks. This is due to the removal of water from the diatomite structure by differential thermal analysis it was found that water from the diatomite structure is removed up to 950 °C. A further increase in the firing temperature to 1200 °C leads to an increase in the density of the samples to 1.12 kg/cm<sup>3</sup>.

Thus, in laboratory conditions, the diatomite brick samples of grade M150–M400 were obtained, medium density class – 1.2, in terms of thermal characteristics relating to the group of effective products with a thermal conductivity coefficient of masonry in the dry state above 0.24 to 0.36 W/(m·°C) in accordance with [27].

The frost resistance of the samples was determined by an indirect method. It was established that samples of bricks fired in the temperature range of 1150–1200 °C will have a high frost resistance, since a frost resistance coefficient of less than 0.85 was obtained only from these samples.

A technical scheme for producing brick based on Il'insky deposit diatomite was developed. It includes the following sectors: diatomite extraction → transport to the raw material store → drying to moisture content 20–25% (drying drums) → crushing and grinding to a size of less than 3 mm (roller crushers and runners) → semi-dry forming at a specific pressing pressure of 100 kg/cm<sup>2</sup> and a humidity of 20–25% → drying of products to a moisture content of not more than 5% → products firing at 1150–1200 °C.

### 3. Conclusion

The diatomite mineral composition of the Il'insky deposit was studied using X-ray diffraction and differential thermal analysis. In addition to the main amorphous phase in an amount up to 77%, the presence of ferruginous montmorillonite clay in an amount of up to 10% and quartz sand up to 4% has been established. The chemical composition of diatomite refers to acidic aluminosilicate raw materials with a high content of coloring oxides. The ceramic properties of diatomite are investigated. It was found that the diatomite refers to the medium-dispersed, a medium-plastic, nonbaking up to 1200 °C raw material. Samples of ceramic building bricks grade of M150–M400 have been obtained by semi-dry forming method. A technical scheme for producing bricks based on Il'insky diatomite is proposed.

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