RAW MATERIALS

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CLAY FEEDSTOCK WITH CARBONATE INCLUSIONS

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Properties of clays with an elevated concentration of carbonate inclusions and experiments on producing building ceramics from such clays are described.

Under the conditions of a market economy the economic situation of plants producing refractories can be improved substantially by widening the range of their products beyond the traditional scope. A diversified range implies a high production level even when the demand for some kind of product is temporarily reduced. It seems natural to organize production of kinds of ceramics other than refractories, including building ones, at refractory-producing plants having ceramics output. The additional articles may not necessarily be produced at the principal production site.

This paper concerns the results of technological investigations carried out at the St. Petersburg Institute of Refractories for estimating the possibility of using Quaternary clays of the Malovisherskoe deposit for producing building ceramics. These clays are known to have a high content of large-grain carbonate inclusions. Taking into account that this material occurs in abundance and is found in practically all deposits of refractory clays in overburden Quaternary loams and clays, the results of our investigations may be of interest for refractory plants that plan to produce building ceramics.

The Malovisherskoe deposit was once exploited by a local brick yard and the clays were investigated at the NIIsokolkeramika about 40 years ago [1]. Due to numerous carbonate inclusions the clays were recommended for production of building brick after drying and grinding. However, the scheme was not realized, and the plant worked using a conventional technology of plastic molding, which gave a high rate of rejects because the carbonate inclusions were poorly treated. The brick yard was closed in the 1960s. The St. Petersburg Institute of Refractories received an order to investigate the feedstock when it was decided to erect new brick works in this region.

The investigated sample of clays had the following chemical composition (% of the dry substance weight): 73.9–74.8 SiO₂, 0.6–0.7 TiO₂, 10.5–10.8 Al₂O₃, 4.2–4.3 Fe₂O₃, 0.9–2.0 CaO, 1.0–2.1 MgO, 2.8–3.0 R₂O, and less than 0.01 S; calcination loss was 3.6%, and water soluble salts were at most 1%. The refactoriness was 1340°C. The mineral content was represented by kaolinite and a large amount of quartz in the form of 0.01–0.09-mm grains. Impurities were represented by calcite, hematite, gypsum, feldspar, chlorite, etc. Large-grain inclusions were mainly metamorphic shales, igneous rocks like granite or diabase, carbonate, and quartz. The total amount of large-grain inclusions was rather high (over 6%) and more than one-fourth of them (more than one-third in grains exceeding 3 mm) were highly active carbonates, which is more than is admitted by the OST 21-78-88 standard (see Table 1). The percentage of other fractions (in the dry clay), % was as follows: 6.3–6.7 of 0.5–0.2 mm grains, 5.7–19.1 of 0.2–0.09 mm grains, 7.0–21.0 of 0.09–0.063 mm grains, 22.0–24.9 of 0.063–0.01 mm grains, 16.4–17.9 of 0.01–0.001 mm grains, and 17.9–20.2 of grains smaller than 0.001 mm. The chemical and grain composition of the clay corresponded to the requirements of OST 21-78–88 imposed on clay feedstock. A comparatively small fraction of fine grains (18–20% of grains smaller than 1 mm) and a considerable amount of sand (about 33% of the 0.5–0.063 mm fraction) were responsible for the low sensitivity of the clay to drying; the sensitivity coefficient according to Z. A. Nosova was $K_s = 0.74$ [2]. The clay was moderately plastic, the Attenberg plasticity number being 8.
TABLE 1. Large-Grain Inclusions in Clay

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Weight fraction, %, of grains of size, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total content, % (&gt; 0.5 mm)</td>
<td>&gt;5</td>
</tr>
<tr>
<td>Carbonate content, % of weight fraction</td>
<td>1.5 - 3.3</td>
</tr>
<tr>
<td>Carbonate content, % of clay weight</td>
<td>47.0</td>
</tr>
<tr>
<td>Activity of carbonate inclusions, %</td>
<td>0.68 - 1.55</td>
</tr>
<tr>
<td>Admissible content of carbonate inclusions by OST 21-78-88, %, at most</td>
<td>Inadmissible</td>
</tr>
</tbody>
</table>

the cohesion was low (1.6 – 1.9 MPa), the relative humidity of puddled clay was 13.8 – 14.5%, and the air shrinkage was 4.6 – 5.1%. The results obtained on firing molded specimens are presented in Fig. 1. Sintering to at most 5% water absorption did not occur before the temperature reached 1150°C (when the specimens already showed dead burn), which can be explained by a high quartz content and a comparatively low content of alkali oxides. Nonetheless, the strength characteristics were rather high.

Full bricks molded from clay ground to a grain size less than 2 mm and burnt at 1050°C had the following properties: water absorption 12.7%, apparent density 2.0 g/cm³, ultimate compressive strength 20 MPa, ultimate bending strength 4.8 MPa, and frost resistance more than 35 cycles.

Steaming the burnt bricks revealed lime inclusions up to 2 mm in size, but no bugles with a diameter of 10 mm or greater and no cracks. All defects were within the limits admitted by the GOST 530–80 State Standard. These experiments show that since the clay is highly sanded and only slightly sensitive to drying, it can be used in brick production without leaning by sand and chamotte, which simplifies the process equipment.

We know of recommendations on preventing brick defects due to carbonate inclusions by introducing up to 0.75% common salt into the clay mixture. This method has been tested and proved efficient, though multiple light spots 2 to 3 mm in size appeared on the surface of specimens. Microscopic investigation of the spots revealed sodium silicate compounds and calcium bound in insoluble compounds. Such spots are admissible on common brick but are undesirable on face brick and tile. Taking into account the additional expenses on the admixture and the difficulties of its introduction when processing lumpy clay with opencast humidity, this method seems to be hardly realizable.

Semi-industrial tests were carried out at the Institute’s experimental technological site in Borovichi and at the Borovichi brick plant. The clay (12 tons) was ground in a cutting machine and then passed successively through rolls with 15-mm and 3-mm gaps and a screw conveyor, after which it was weathered for 7 days. The experimental burnt bricks broke upon steaming because of cracks 3 – 4 mm in length forming along the carbonate inclusions.

In order to reduce the size of inclusions, the clay was additionally passed through rolls with 1.5-mm gaps. Since the rolls were rather short, up to 0.2% 2 – 3-mm carbonate inclusions remained in the clay.

Bricks 89 mm thick with a hollowness of 24% were molded in an SMK-28A auger extruder at a relative humidity around 16%. Green bricks were dried in cars in a tunnel dryer for 42 h. The temperature of the drying agent at the inlet was about 110°C, the green humidity after drying was 1.7%, and from 1 to 3% of the bricks were rejected. A part of the bricks in a 14-row charge (1.75 m) was burnt in a 70-m tunnel furnace for 32 h and kept at 920°C for 3 h in accordance with the technology used in the yard. The charge was not deformed. Rejects due to fractures constituted 3.9%. Nonetheless, the burning temperature turned out to be insufficient for the investigated clay, because the bricks had a low mechanical strength and were liable to cracking when stored. When the bricks were burnt at 1000°C with the same height of the charge in a gas-fired batch furnace, where the temperature rose for 20 h, only 2.2% were rejected. Brick tests gave the following results: water absorption 9.5%, apparent density (within clearance limits) 1500 kg/m³, ultimate compressive strength 10.9 – 12.6 MPa, ultimate bending strength 2.7 – 2.9 MPa, and frost resistance more than 35 cycles. Some bugles, whose size and number were within the limits...