Petrographic study of coarse-grained inclusions in clay raw materials

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Abstract. The article presents the results of standard assessment of coarse-grained inclusions of low-melting clay raw materials taken from four fields. It is shown that such an assessment of coarse-grained inclusions does not give a complete picture of their properties and grain size composition. Further detailed studies of coarse-grained inclusions are performed by microscopic and petrographic methods. The microscopic method was applied when each fraction of inclusions was investigated in the transmitted and reflected light while using a lens of 8x and at an ocular of 9x, field of view diameter being 2.4 mm. The following characteristics of inclusions were defined: size, color, gloss, porosity (pore configuration, their size, quantity and character). The researchers paid special attention to the study of field of view of different fractions, determining clay raw materials stability of properties and causing defects formation. The difference of carbonate inclusions for the clays under study was determined. The type of coarse-grained inclusions, their structure and size can affect the quality of ceramic materials and should be taken into account in production technology. The obtained results will allow predicting the quality of ceramic materials from the investigated clays.

1. Introduction

Many regions have significant reserves of brick-tile clay raw materials. Clays of a number of fields are used for ceramic bricks production. Despite modern production, there are defects in the manufactured products [1,2]. The main reasons for defects formation are the instability of the composition of raw materials and the presence of coarse-grained inclusions [3-8].

In order to improve the ceramic products quality, large-grained inclusions of four clay fields of the Samara Region have been studied.

2. Methods and materials

The investigations were carried out on brick-tile clays of four fields in the Samara region: Alekseevsky, Kinel-Cherkassk, Pustovalovsky and Neftegorsk.

The experimental work was mainly based on the techniques and methods adopted for the research practice on ceramic materials and ceramic brick technology [9]. Coarse inclusions, originally established by the standard method, were investigated in detail [10]. The microscopic method was applied when each fraction of inclusions was investigated in the transmitted and reflected light while using a lens of 8x and at an ocular of 9x, field of view diameter being 2.4 mm [11-13].
3. Results

In accordance with the standard method, samples weighing 1 kg of each clay were chosen. They were filled with water and soaked for 24 hours. Water volume exceeded 3-4 times the clay raw materials volume. The stirred slurry was then passed through a mesh screen № 0.5. Then the screening residue was placed under a stream of water and washed until the water that passed through the mesh screen became transparent. The resulting residues were dried at 105°C to constant weight, and then sieved through a set of screens with 1, 2, 3, 5 grids. The screening residue was weighed and inspected. The results are shown in Figure 1.

Clays samples from all investigated fields in the Samara region (Alekseevsky, Kinel-Cherkassk, Pustovalovsky and Neftegorsk) belong to one group: by the number of coarse inclusions to a group with an average content, in size to a group with small inclusions, and by inclusion type to carbonates and quartz inclusions [14].

![Figure 1. Granulometric composition of coarse-grained inclusions.](image)

As can be seen from the data presented in Figure 1, despite the fact that all the test samples belong to the same group in terms of the number, size and inclusions type, the granulometric composition of coarse-grained inclusions is different. It is particularly true for Pustovalovsk field clay, where the number of inclusions is several times greater than in the other clays.

The total volume of inclusions and their distribution by fractions is clearly shown in Figure 2. From this figure it follows:

- the smallest number of inclusions in Kinel-Cherkassk field clay;
- the greatest number of inclusions - in Pustovalovsky field clay;
- the largest inclusions are present in Neftegorsk field clay;
- the greatest number of small inclusions - in Pustovalovsky field clay.

However, visually, without zooming, it is difficult to evaluate the nature of coarse-grained inclusions.
Microscopic method determined the following characteristics of inclusions: size, color, gloss, porosity (pore configuration, size, quantity and their nature).

Alekseevsky clay: In the clay of the Alekseevsky field it is established that the mineral composition of inclusions of different fractions is different. The largest inclusions (more than 3 mm in size) are represented by conglomerates of carbonate and quartz grains (Figure 3, a)). For fractions larger than 1 mm, the main type of inclusions are conglomerates of quartz grains cemented with clay (Figure 3, b)). Carbonate inclusions predominate in fine fractions, which are also found in large fractions. Individual grains have a tubicolous structure.

Kinel-Cherkassk clay: Carbonate porous inclusions are present in all fractions. In small fractions of inclusions (on a screen 1 or less), a large number of tubicolous beige carbonate formations are present having the size from 1 to 3 mm, the length, and the width 0.5-1.5 mm.

Neftegorsk clay: In clay, carbonate inclusions are the main type of inclusions in all fractions. Inclusions structure differs from similar inclusions in the other clays, it is more dense, practically without pores. Grains have angular shape.

Pustovalovskiy clay: The structure of carbonate inclusions is close to the inclusions of Neftegorsk field clay. Individual grains have increased porosity.

Figure 2. Coarse-grained inclusions type.
Figure 3. Characteristic inclusions in the clay of the Alekseevsky field: a) inclusions of more than 3 mm in size; b) inclusions more than 1 mm; c) inclusions more than 1 mm; d) inclusions of 0.5-1.0 mm in size.

4. Discussion

The nature of coarse-grained inclusions in the investigated clays, despite the fact that the clays of different deposits belong to the same group in terms of the number of coarse-grained inclusions, in size and type of inclusions, is different.

The predominant carbonate inclusions have different structure. Porous varieties with less strength are present in the clays of the Alekseevsky and Kinel-Cherkassk fields. The tubicolous structure is more typical for the Kinel-Cherkassk clay. The most dense structure of carbonate inclusions is in the Neftegorsk field clay.

It can be assumed that the strength, porosity and voidness of carbonate inclusions, within the same amount, can have different effect on the quality of fired ceramic products, namely, the blistering. The denser the structure, the more intense the influence will be.

The size and appearance of quartz inclusions can also have different effect. It is known that the smaller the size of quartz grains, the more even the structure and less negative impact of polymorphic transformations. Quartz inclusions in the form of conglomerates are most dangerous at the cooling products stage, since they can be stress concentrators in the temperature range of polymorphic transformations, especially at 573°C.

Large plant residues are the cause of the formation of structure voids and heterogeneity.

Based on the obtained analysis results, it can be assumed that, under the same preparation conditions, the highest-quality ceramic products will be made from the clay of the Kinel-Cherkassk field. The greatest number of defects can be in products made of the Neftegorsk field clay for it contains the largest and densest limestone inclusions. To obtain high-quality products, especially from clays of Alekseevsky and Neftegorsk fields, it is necessary to provide either the enrichment of raw
materials and the removal of inclusions, or fine grinding in technology. Under such conditions, a wide range of ceramic products can be produced from all the investigated clays, using the developed method [15] and directed regulation of the degree of sintering [16].

5. Conclusions
The conducted researches of brick-tile clays of four fields of the Samara region allowed to establish the following:

1. In accordance with the current clay raw materials classification for the ceramic industry, all the clay samples from different fields belong to the same group: by the number of coarse inclusions to a group with an average content, in size to a group with small inclusions, and by inclusion to a group with carbonates and quartz inclusions.
2. The standard coarse-grained inclusions evaluation of clay raw materials does not give a complete idea of their form and granulometric composition.
3. The clays are heterogeneous in composition, they differ in appearance and coarse-grained inclusions quantity.
4. The coarse-grained inclusions type, their structure and size may affect the quality of ceramic materials and should be taken into account in production technology.

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