Ceramic Composition Material with Mullite Crystals Obtained from the Clayy Raw Material of Yakutia

M P Lebedev¹, V N Tagrov², E S Lukin²

¹FRC "Yakutsk Scientific Center SB RAS"; 677980, Yakutsk, st. Petrovsky, 2
²Larionov institute of physical-technical problems of the North SB RAS, Oktyabrskaya street 1, Yakutsk, 677000, Russia

E-mail: m.p.lebedev@prez.ysn.ru, vn_tagrov@mail.ru (corresponding author), lukines@iptn.ysn.ru

Abstract. The article deals with the manufacture of modern structural ceramic materials from clay and loam deposits of the Republic of Sakha (Yakutia). The importance and relevance of the development of the production of building materials from local raw materials is emphasized, since this will certainly affect the effectiveness of the construction complex as a whole. The successful development of the construction complex is capable of not only stimulating growth in all sectors of the economy, but also contributes to solving the most pressing social problems. Today, Yakutia has huge reserves of mineral raw materials for the production of a wide range of building materials and products. Of practical interest are wall materials made from clay soils. Given the features of the region’s raw material base, this work focuses on additional processing of traditional material. Controlling the complex physicochemical and structural-mechanical transformations that occur during heat treatment, a methodology has been developed for creating a composite material that will allow competitive innovative materials with enhanced strength properties to be produced with a reinforcing element with a glassy phase matrix of mullite crystals. The fabricated samples have a wide range of physical and mechanical properties and allow using it as a high-quality structural building ceramics, as well as industrial floor technical tile.

1. Introduction

Ceramics has always been and is at the intersection of science, technology and art. The history of ceramics goes back thousands of years. Ancient ceramics continue to serve science, helping to study the development of mankind. As is known since ancient times, clay materials during firing form a strong material having a rather complex structure, in which particles of various compositions and sizes are present. Such materials began to be called ceramic [1].

Among all known new high-performance materials capable of working in extreme conditions, ceramics is gaining more and more recognition. Having a unique combination of electrophysical, physico-chemical, thermally stable and artistic-aesthetic properties, ceramics has no equal. Understanding the processes occurring during sintering and improving the technology of manufacturing ceramics and composite structural materials will allow developing competitive innovative materials from local raw materials [2].

Development of the production of building materials, the development of the construction complex as a whole. Successful development of the construction complex, not only in all sectors of the
economy, but also in solving the problems of the most acute social problems. Many problems of the construction complex are due to the insufficient efficiency of the operation of the industrial production of building materials [3]. Russia is on the verge of fulfilling the most important strategic tasks and implementing investment projects, in this regard it is very important to create conditions for the development of the building materials industry in the regions [4].

The Republic of Sakha (Yakutia) has vast reserves and various types of clay that can be used in the production of wall materials [5]. According to the consolidated balances of deposits of building materials as of 1982, the number of clay and loam-containing deposits for brick production totals about 30 deposits. Basically, bricks of the building grade M50, M75, M100 (strength 5MPa, 7.5MPa, 10 MPa) were obtained from them [6]. Currently, these deposits are practically not used. The traditional technology of ceramic building materials, including those used for internal and external cladding of buildings and structures, is based largely on the use of high-quality ceramic raw materials. At the same time, increasing the production of ceramic materials, which is the most material-intensive, requires the involvement of significant amounts of natural resources, the need to involve low-quality raw materials in production, which need to be adjusted and improved [7].

2. Relevance
The aim of this work is to develop the technology of manufacturing environmentally friendly ceramic clinker materials with high strength, from local raw materials adapted to the natural and climatic conditions of the Far North and the Arctic.

This direction includes the development and production of ceramics – which is a composite material with a vitreous phase-matrix reinforced with small crystals of mullite [9]. This will expand the range of applications of ceramics from local raw materials, depending on its purpose (Fig.1), through the selection of raw materials, additives of leaner and flux, and production technology features.

In the chemical materials science of ceramic materials, the issue of mullitization is given special importance, since it is mullite that mainly determines the operational properties of ceramic products. Mullite is the only aluminosilicate $3\text{Al}_2\text{O}_3\cdot2\text{SiO}_2$, stable at high temperatures (up to 1800°C), which has a number of unique physical and chemical properties and is one of the crystalline phases in many ceramic materials. Mullite can have an amorphous structure, or represent crystals in the form of prisms, needles and fibers. The most valuable of these forms are fibrous and needle single crystals, which are used as a strengthening component in the production of high-quality ceramics [10].

In modern construction, it has become popular to use ceramic blocks made by forming and firing clay. Such blocks gained their popularity due to their uniqueness and high qualities, as they are considered “warm ceramics”. Ceramic blocks, which are more durable and durable, unlike ordinary bricks, have large dimensions and are formed hollow. Due to the formed voids in ceramic blocks, low thermal conductivity is achieved, so it belongs to energy-saving building materials. Ceramic blocks can also be successfully used in areas with high seismic activity. Similar to any other building material, the type of brick structure and layout of the building should be chosen in accordance with the requirements depending on the level of seismic activity [11].

3. Calculations and results
Products made from local raw materials are the main types of structural ceramics, maintaining the level of water absorption in the range of 8-11% in accordance with the requirements for building bricks, and thus have a compressive strength of 40 to 80 MPa, which correspond to the brands M400 and M800. For comparison, the construction concrete block has an average strength of 4.5 – 25.69 MPa [12]. In addition, ceramic blocks have good frost and heat resistance.

During the development of the technology, with changes in the composition and parameters of the temperature regime, controlling the formation of mullite glass phase, samples of ceramic products with water absorption of less than 3%, with different strength characteristics from 90 MPa to 140 MPa were experimentally obtained. According to the technical characteristics of the samples obtained
correspond to paving clinker tiles for paving slabs, while paving slabs of concrete has a strength of only 28.9-51.37 MPa [13] (Table 1).

**Table 1.** A slightly more complex table with a narrow caption.

| Parameters and characteristics | Concrete Block | Ceramic bricks | The resulting ceramic mass | Concrete Paving slabs | The resulting ceramic mass |
|--------------------------------|----------------|----------------|---------------------------|------------------------|---------------------------|
| Strength, MPa                  | 4.5-25.69      | 2.5-25         | 40-80                     | 28.9-51.37             | 90-140                    |
| Water Absorption, %            | 9-18           | 12-18          | 8-11                      | 5-6                    | <3                        |

It should be noted that the obtained experimental ceramic material fully complies with the modern requirements of resistance to temperature extremes, water resistance and chemical resistance, has a high degree of wear resistance to abrasion, durability and strength. It can be used as an industrial floor. This material is able to provide maximum protection for flooring in modern industries. Moreover, foamed ceramics with good thermal insulation characteristics can be made from local raw materials (Fig. 1).

![Figure 1. Samples of ceramic foam.](image1)

To determine the presence of mullite in the obtained ceramic samples, an analysis was performed on an X-ray diffractometer with a Theta-Theta goniometer Ultima IV, in the range of angles from 7.0000º to 162.0000º for 2, CoKα. Typical X-ray diffraction patterns of a calcined sample of local lay with different mullite contents are shown in Fig. 2 and 3.

![Figure 2. X-ray diffraction pattern of a burnt crock of local clay with a mullite content of 1%.](image2)
Figure 3. X-ray diffraction pattern of a burnt shard of local clay with a mullite content of 36.7%.

Today, the Russian market, including the Far East region, quality clinkers are supplied from Europe, the price of which is highly dependent on the exchange rate, in particular the Euro. Introduction of scientific developments on the developed technology will allow to master production of high-quality and environmentally friendly products from local raw materials, for implementation of policy of import substitution.

According to H. Salmang., clay supplied in the production of bricks and clinker are rich in fluxes, especially iron. Sometimes, there is no clay substance in them at all, that does not prevent them to be the raw material suitable for certain purposes. Ordinary red brick is fired at a temperature of about 900°-1050°C. For this reason, for its manufacture can be used and poor alumina clay. With an increase in the firing temperature by 100°-200°, a diffusion process occurs and the size of the mullite crystals increases, while compacting the shard to a density characteristic of the stone product (Fig. 4).

Figure 4. Seals of the annealed shard.

The clinker obtained in this way is a very valuable construction and road material. The same clay with more thorough enrichment are also used for the manufacture of pottery, tiles and artistically household ceramics [6]. Figure 5 shows samples of household ceramics made from local raw materials [14].
4. Conclusion
Clinker brick is currently in demand by the market, but at the moment in Russia, due to a shortage of high-quality clay raw materials, it is being delivered from abroad. [8] But different types of additives are used to make clinker bricks. As an analysis of the literature shows, to obtain clinker bricks, various ceramic materials based on refractory clays [15], based on special clays [16]; with the addition of diatomite and flask [17], with the addition of waste [18]; the addition of slag TPP [19]; and complex additives [20].

As the experiments in this work have shown, by controlling and controlling the physicochemical processes and structure formation of materials, high-tech products can be created from local clay that will allow the production of competitive innovative materials with desired properties. The fabricated samples have a wide range of physical and mechanical properties and allow using it both as artistic household ceramics and as high-quality structural building ceramics.

Thanks to the X-ray fluorescence analysis, the presence of mullite in the obtained ceramic samples from local raw materials was established. It is shown that, from local clay, it is possible to obtain ceramic products for various purposes with a wide range of physical and mechanical properties, which will enable priority development and expansion of the raw material base of ceramic materials from local clay.

Due to the margin of safety of the obtained ceramic composition from local raw materials, depending on the region of application and use for filling the voids of the insulating material, ceramic blocks will allow building buildings with relatively thin walls and at the same time meet high requirements for thermal protection and sound insulation [21].

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