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Peculiarities of non-autoclaved lime wall materials production using clays

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Abstract. At present, the development and implementation of energy saving technologies for building materials production, which correspond to modern trends of «green» technologies, become ever more popular. One of the most widely spread wall materials today is a lime brick and stones. The primary raw goods used in production of such materials are quarziferous rocks. However, they have some disadvantages, including low strength index at the intermediate phase of their production, especially in case with a raw brick, which is an issue in the production of high-hollow goods due to low strength index of raw materials and the nonoptimal matrix structure. The conducted experiments confirmed the possibility to control structurization of building composites due to application of nonconventional argillous raw materials. Besides, the material and mineral composition of nonconventional clay rocks ensures the optimal microstructure thus providing for the production of efficient wall building materials via energy saving technology.

1. Introduction

At present, the development and implementation of energy saving technologies for building materials, which correspond to modern trends of «green» technologies, which preserve the environment and ensure comfortable living conditions, become ever more popular. The decrease in fuel consumption eliminates the emission of greenhouse gases into the atmosphere and reduces the level of hazardous pollution of soil, water and air.

With regard to economic efficiency, the technology of lime brick production differs fundamentally from clay brick production. For example, the technology of lime brick production consumes far less energy (by 3.5 times), much less fuel (by 2.5 times), and less manpower. All this combined will not only contribute to the decline in the final cost of materials, but also to the improvement of ecological situation.

The lime brick and stones are widely spread in building industry. They are applied in wall facing and construction, and at times in restoration of destroyed buildings. Another important property of this material is enhanced sound insulation, which is relevant for noise protection. The primary raw goods used in production of such materials are quarziferous rocks. However, they have some disadvantages, including a low strength index at the intermediate phase of their production, especially in case with a raw brick, which makes it complicated to obtain materials with enhanced thermal and sound insulation properties. Such class of materials is being developed and produced in many countries, especially in

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Russia, thus creating a sustainable basis for such materials produced with raw materials of different genesis. For example, there are technologies for wall material production, which imply utilization of various technogenic and industrial wastes. In this respect, clay rocks deserve particular attention [1-4].

Currently various countries worldwide adopt standards and guidelines (SG) for raw materials to produce a specific type of building materials. These specific types of raw materials shall correspond to all characteristics listed in the SG.

Experts and geologists in particular, look for raw deposits, which would satisfy the specified requirements. Thus, geologists disregard raw materials, which according to their characteristics, do not meet the specified requirements, however such raw materials are in abundance these days.

In order to solve the above task there is a need to reconsider the design and technology of building materials synthesis, which includes search of new types of raw materials and modernization of existing composite production technologies [5-6].

At present, enourmous research effort was put with regard to fundamental studies in order to expand raw materials base for the synthesis of silicate materials. In particular, it was suggested to use alumino-silicate rocks as active components of similar wall materials, which will further contribute to dense and highly organized structure of obtained composites [7-8].

2. Materials and methods

Lump quicklime of JSC Belgorodmaterialy (GOST 9179-77) was used as a cementing component. The work mainly focused on aeolian sedentary deluvial clay rocks of the Quarternary period found in deposits of the Kursk Magnetic Anomaly.

MicroSizer 201 facility was used to determine particle size distribution of materials. The facility makes it possible to define particles in the size ranging from 0.2 to 600 μm.

X-ray diffraction analysis was used to study the mineralogical composition of raw materials and new synthesized composites. The study was conducted using the ARL X'TRA model of X-ray diffractometer by Thermo Fisher Scientific. Differential thermal analysis was used alongside with X-ray diffraction analysis to identify new products and their mineral composition. Derivatograph Q – 1500 D was used to conduct the tests. MIRA 3 LM microscope was used for scanning electron microscopy (SEM).

The production of samples depended on raw mix composition. If only burnt and ground lime was used as a cementing component, then the mix was prepared by mixing the input components in required volumes.

The compound, which included preliminary prepared cementing composition (preliminary ground clay rock and cementing component), was mixed with the basic rock or similar silica-containing component and watered. Upon formation the samples were placed in a steam chamber and were exposed to steam curing at 90-95 °C with the following processing mode: 1.5 h + 9 h + 1.5h.

3. Main part

The main properties of obtained silicate products fully depend on new formations synthesized during steam curing. The composition of obtained new formations directly depends on initial raw components and steam curing modes. Therefore, the production of highly crystallized new formations thus ensuring dense structure remains an urgent task.

The objective of this work is to study the influence of the nonconventional clay structure on properties of non-autoclaved silicate materials and to analyze structurization mechanisms under the impact of the lime component on clay rocks during steam curing.

The majority of clay rocks have a complex polymineral composition [9-11]. Clay is characterized by high dispersion, which preconditions its active interaction with a cementing component (quicklime). It should be noted that rocks composed of clay minerals in various quantities represent a complex system with various properties. The activity of such raw materials depends on their formation genesis.

If to consider the system of clay component–inorganic cementing composition, it is possible to account, on the one hand, qualitative dependence on strength index and stability of properties, and on the other hand, the amount of cementing component. Parameters of this dependence will be contingent upon the role of cementing component in structurization and on its ability to interact with components of active rocks.

Thus, the understanding of clayed rock properties and correct application of such raw materials will contribute to synthesis of composites with set properties [12-14]. It is only possible to make a proper building composite on the basis of clay rocks through integrated impact on rocks by chemical action, mechanical exposure, etc., which together form a closed-loop produciton process. When clayed rocks are exposed to treatment, it is necessary to create the period for curing and composite microstructure formation, to maintain certain temperature and humidity of the environment.

Clay rocks of the Kursk Magnetic Anomaly were used in the study. The grain size composition of rocks obtained through sieve analysis is presented in Tab. 1.

Table 1. Grain size composition

Fraction content, wt. %, sieve size, mm								
over 0.315	0.315–0.20	0.20–0.125	0.125–0.10	0.10–0.05	0.05–0.04	0.04–0.01	0.01–0.005	less than 0.005
1.3	2.95	5.10	6.35	12.90	5.82	42.95	5.70	16.93

The pelite fraction of rocks represents montmorillonites, hydromicas, kaolinites, mixed-layer nanosized formations and X-ray amorphous compounds (Fig. 1).

These rocks are also widely spread. However, the majority of such rocks fails to satisfy raw standards and guidelines suitable for production of indicated building materials, but their material composition provides for the production of silicate materials of non-autoclaved curing.

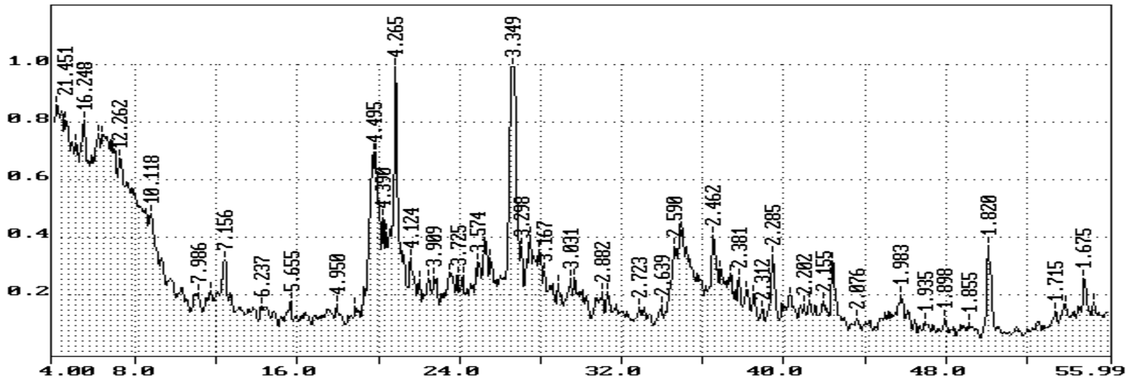

Figure 1. X-ray diffraction pattern of pelite fraction

The objective of the study was to determine rational content of pelite fraction within source raw materials, to develop compositions ensuring optimal structurization and to make silicate materials with high physical and mechanical performance. The pelite fraction was obtained by elutriation of soure sandy and clay rocks. Particle-size distribution within pelite fraction and source rocks was determined via laser granulometry using MicroSizer 201 installation (Fig. 2). The pelite fraction mainly contains particles with the size ranging from 0.7-10 μm.

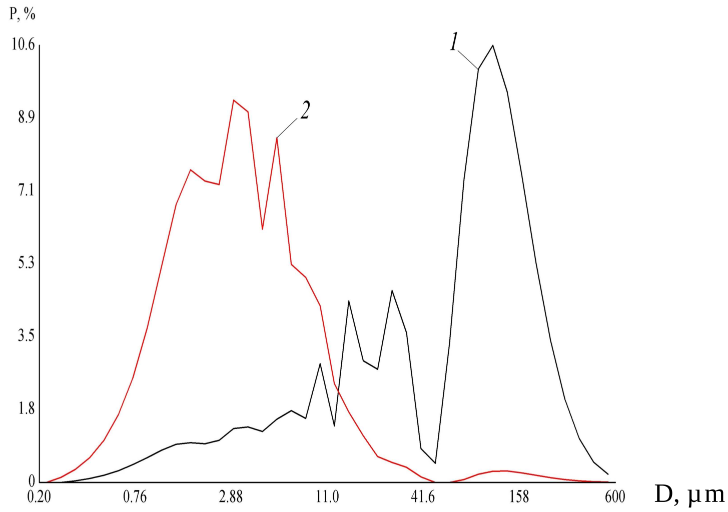

Figure 2. Particle-size distribution: 1 – source clay rock; 2 – pelite fraction

The experiment was based on the mathematical planning method. Experimental conditions are shown in Tab. 2.

Table 2. Experimental conditions

Factors		Variability levels			Variability interval
Natural form	Coded form	–1	0	+1	
CaO, wt. %	x1	6	10	14	4
Pelite fraction content, wt. %	x2	10	20	30	10

The objective of factors variation was to identify their rational value providing for material production with required characteristics. Mathematical change models of physical and mechanical properties of silicate samples were obtained after statistical computational processing of experimental data.

Complex influence of CaO content and composition of pelite fraction on physical and mechanical properties of non-autoclaved silicate products is presented on nomographic charts (Fig. 3-4) built with a regression equation.

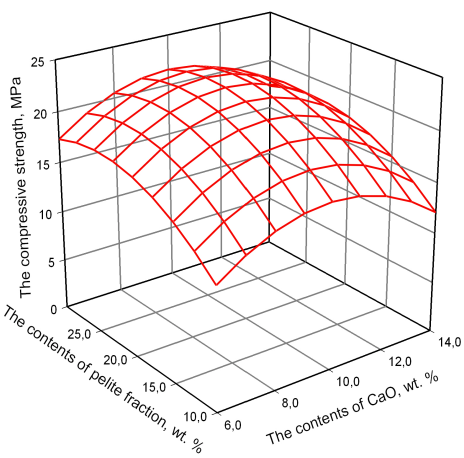

Figure 3. Nomographic chart of compression strength dependence on pelite fraction and lime content

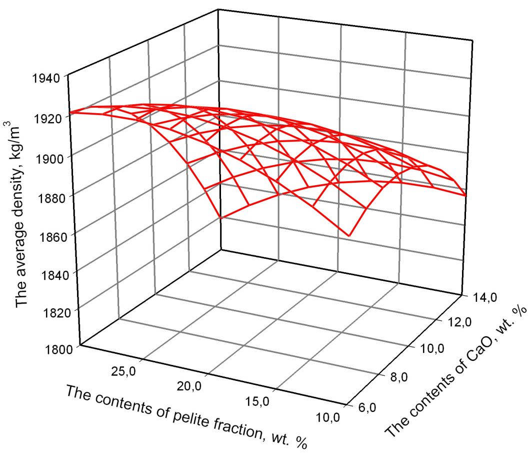

Figure 4. Nomographic chart of mean density dependence on pelite fraction and lime content

The obtained data (Fig. 3) indicate that samples containing 10 wt. % of lime and 20 wt. % of pelite fraction reach the maximum strength (22 MPa). The strength almost does not change with the increase in pelite fraction to the 30 wt. %. The increase in lime content to 14 wt. % reduces the strength to 18 MPa.

According to differential, thermal and X-ray diffraction analyses, new formations mainly represent poorly crystallized compounds of hydrated calcium silicate (CSHB) and C_2SH_2. The interaction of lime with clay minerals in steam curing conditions leads to the reduction of connection between silicon-oxygen tetrahedrons and aluminum atoms in a crystal lattice of a clay mineral. Hence, alumina, silica and X-ray amorphous substance may react with calcium hydroxide.

The presence of nanosized aluminosilicate particles in clay sands, loams and clays, as well as fine-grained active quartz in alkaline conditions leads to the formation of tobermorite hydrosilicates of various basicity and hydrated calcium aluminosilicates.

Thus, a fine-grained part of clay rocks serves as an active hydraulic additive, and lime in this case is naturally transformed into a hydraulic binding agent. High temperature conditions of steam curing fosters the formation of cementing compositions, which takes place during lime-clay interaction. This gives building materials better physical and mechanical properties.

It is found that the content of pelite fraction has great impact on strength properties of silicate materials made on the basis of a clay sand. At the same time all compositions with 20 wt. % of pelite fraction ensure high strength properties and a good water resistance ratio of materials, and a further increase in mass does not lead to considerable increase in strength. It is of practical importance since variations of raw material composition, which are inevitable in real production, make it possible to produce building materials with set physical and mechanical properties.

The increase in the strength of samples alongside with the increase of pelite fraction in source rocks leads to the increase of new formations and formation of more dense cementing compositions. It can be assumed that the content of 20 wt. % of pelite fraction and X-ray amorphous phase is sufficient for the formation of solid microstructure of cementing binding agents and the increase in fine-grained component does not lead to considerable increase in strength.

4. Conclusions

Thus, physical and mechanical properties of non-autoclaved silicate materials on the basis of clay rocks with various genesis will strongly depend on pelite fraction composed of the X-ray amorphous phase and fine-grained quartz. The optimal content of pelite fraction in clay rocks makes approximately 20 wt. %. Such composition of clay rocks ensures the formation of strong microstructure of cementing binding agents in steam curing conditions, which will provide for the production of efficient wall building materials via the energy saving technology.

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