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Influence of man-made aluminosilicate raw materials on physical and mechanical properties of building materials.

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Abstract. It has been identified that man-made aluminosilicate raw materials represented by clay rock of varied genesis can be used as energy-efficient raw materials to obtain efficient highly-hollow non-autoclaved silicate materials. A technique of structure formation in the conditions of pressureless steam treatment has been offered. Cementing compounds of non-autoclaved silicate materials based on man-made aluminosilicate raw materials possess hydraulic properties that are conditioned by the process of further formation and recrystallization of calcium silicate hydrates, which optimizes the ratio between gellike and crystalline components and densifies the cementing compound structure, which leads to improvement of performance characteristics. Increasing the performance characteristics of the obtained products is possible by changing the molding conditions. For this reason, in order to create high-density material packaging and, as a result, to increase the strength properties of the products, it is reasonable to use higher pressure, under which raw brick is formed, which will facilitate the increase of quality of highly-hollow products.

1. Introduction

The history of using silicate materials covers over one hundred and twenty five years. This building material was invented in the end of the 19th century, in 1880, in Europe by a German engineer. Virtually throughout all of its history, the technology of manufacturing this material had been imposing strict requirements on the content of clay minerals in raw materials (quartz sand or quartzose component).

Recent researches of obtaining wall building materials through autoclaving with adding clays of various genesis have shown that it is possible to obtain wall bulding composites with stable characteristics. These researches show that with the effect of steam in a closed system under high pressure with the use of aluminosilicate raw materials and lime, it is possible to synthesize waterproof rock. The characterisitics of the obtained synthetic rock depend on the curing conditions and the composition of the initial mixture.

Obtaining composites with the highest parameters on the basis of clay rock of various genesis is also possible by means of close contact of all of the system's components. This solution became possible owing to the use of compaction. It has also been noticed that use of clay rock as the active component facilitates a sufficient decrease of pressure under which the product is steam-cured.

Most aluminosilicate rocks have a complex polymineral composition [1-2]. This way, clay rocks can consist of silicon oxides, iron oxides, aluminum oxides, as well as aluminosilicates [3-6]. Besides, clay minerals, compositions of clay rock include sand and other fine particles [7], which can also possess the capability of interacting with calcium oxide (quicklime).

The principal properties of the obtained silicate products completely depend on new formations which are synthesized during steam treatment [8-9].

Analysis of research of properties of new formations in building systems, particularly calcium silicate hydrates, based on aluminosilicate raw materials has shown significant variation in their influence on the building systems' properties [10-11]. Thus, for example, calcium silicate hydrates of the low-basic group possess the highest strength parameters while tobermorite has worse characteristics.

The goal of this research is to study the influence of man-made aluminosilicate raw materials represented by non-traditional clay rock on obtaining energy-efficient highly-hollow composites.

2. Materials and methods

The role of binder components was performed by lump quicklime by JSC Belgorodstroimaterialy, GOST 9179–77. The work involved quaternary aeolinan-eluvial-diluvial raw clay from deposits of the Kursk Magnetic Anomaly.

X-ray diffraction analysis was used to study the mineralogical composition of raw materials and the synthesized new formations. Studies were carried out using an ARL X'TRA Thermo Fisher Scientific X-ray diffractometer. Aside from X-ray diffraction analysis, differential thermal analysis was also used to identify the products of new formations and the mineral composition. Research was carried out using a Derivatograph Q – 1500 D device. A MIRA 3 LM microscope was used to carry out scanning electron microscopy (SEM).

The method of producing samples depended on the composition of raw materials. A mix including a prefabricated binder (previously ground clay rock and binder component) was mixed with a base rock or a component with the similar silicon dioxide content and then dampened. After molding, samples were placed in a steam chamber and steam-cured at the temperature of 90–95 °C under the following treatment mode: 1.5 h.+9 h. +1.5 h.

3. Main part

Two types of raw clay from the Kursk Magnetic Anomaly region with high aluminosilicate content were used to solve the problems of creating efficient composites.

The amount of pelite fraction in clay No. 2 is 39 % wt. For raw clay No. 1 this amount is 22.63 % wt. Siltstone and pelite are predominant by size. The chemical composition shows that these rocks have high silicon dioxode content and can be categorized as acidic.

Studying clay rocks using X-ray diffraction analysis revealed the presence of montmorillonite. Peculiar reflexes change their values after two hours of calcination at the temperature of 600 °C, which can be explained by the removal of water between the layers of the clay substance. Also, after calcination at high temperatures, there is a series of reflections which indicate the presence of illite-class minerals in the rock.

Presence of kaolinite is indicated by reflections in the area of 7.138 – 7.2. After two-hour long high-temperature treatment, this series of reflexes disappears, completely proving the presence of kaolinite. Presence of mixed-layer connections in the rock is characterized by reflections in area Q = 8 – 18°.

Quantitative mineral analysis shows that there is the dominant component in the rock composition of SiO2: 35 – 38 %. There are also: calcite (<5 %), feldspar (5-13 %), mica (0.5 – 1 %).

Study of the microstructure of clay rocks (Figures 1 – 2) identified that the structure is of "skeletal" type. There is a large number of microscale level particles in the form of aggregates and clay particles. The habit of crystals is foliated, lamellar and curved in two directions. Particles form microaggregates by chaotic aggregation between each other (by means of mechanical bonds). However, in the entire mass, there are aggregates with well-oriented particles (clay minerals). This allows one to make a conclusion that the clay rocks under study have multicomponent (polymineral) composition. Furthermore, nanoscale level particles are observed in the rock's composition, which can predefine high properties of obtained products.

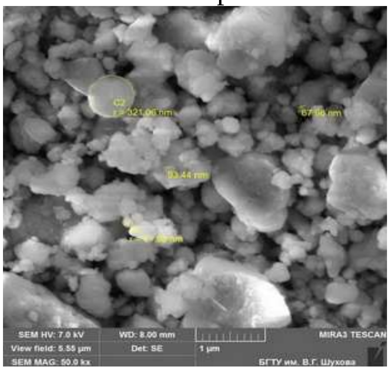


Figure 1. Microstructure of clay No. 1, SEM, ×50000

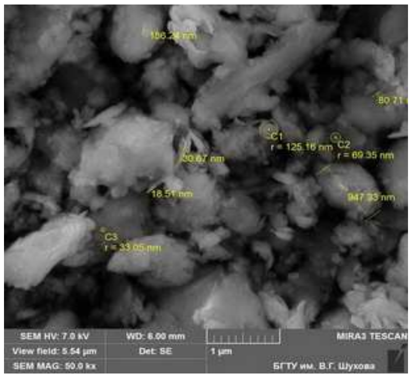


Figure 2. Microstructure of clay No. 2, SEM, ×50000

The standard technology of silicate material production involves a binder obtained by intergrinding two components: quicklime and quartzose raw materials. This facilitates an increase in the binder's dispersity and, consequently, accelerates the process of shaping new formations, which predefines improvement of product characteristics. According to the traditional technique, such binder is obtained in grinding machinery by grinding CaO and SiO_2 in the 1:1 ratio.

To create a more dense structure of the material and accelerate the shaping of new formations, a binder consisting of clay rock and quicklime was obtained. Clay No. 1 and clay No. 2 were used in the experiment.

The raw mixture prepared for the experiment contained 15 % wt CaO (Table 1).

Table 1. Compositions of raw mixtures based on lime-clay binder

Composition No.	Lime content in raw mixture, % wt	Proportion of lime to clay in binder	Specific surface area of binder, m^2/kg
1	15	1 : 1	1000
2	15	1 : 1.5	950
3	15	1 : 2	700

Samples were obtained by compacting under the pressure of 10 MPa. Moisture of the raw mixture depended on its composition and was within the range of 8-12%. After the samples were produced, they were subjected to steam treatment (with the temperature of 90–95 °C) for 12 hours (1.5 + 9 + 1.5). Characteristics of the samples were identified according to the regulatory documents. The results are presented in Table 2 and Figure 3.

Table 2. Physical and mechanical properties of silicate materials based on lime-clay binder.

Physical and mechanical characteristics	Composition No.		
	1	2	3
Clay No. 1			
Compressive strength limit, MPa	15.5	16	16.8
Softening ratio	0.73	0.8	0.8
Average density, kg/m^3	1655	1680	1670
Water absorption, %	11.6	9.8	9

Clay No. 2			
Compressive strength limit, MPa	15.1	15.7	15
Softening ratio	0.72	0.72	0.7
Average density, kg/m^3	1520	1550	1580
Water absorption, %	14	13.5	13

Increasing the ratio of clay rock in the binder facilitates the increase of the compressive strength limit of the samples based on clay No. 1 from 15.5 to 16.8 MPa. For the samples based on clay No. 2, this increase is negligible and represents an increase from 15.1 to 15.7 MPa. In composition No. 3, a decrease in strength is observed.

The average density value changes insignificantly from 1655 to 1670 kg/m^3 for the samples based on clay No. 1, and from 1520 to 1580 kg/m^3 for the samples based on clay No. 2. The density of these samples is higher than that of those where only quicklime was used as a binder. Water absorption reduced due to the use of such binder, and for the samples based on clay No. 1 this reduction is more substantial. Values of the softening ration also increased.

The microstructure of a sample of composition No. 1 was studied with a scanning electron microscope (Figure 4). The microlevel structure of the obtained sample can be described as contiguous; a dense mass of unoriented new formations is observed in the total mass.

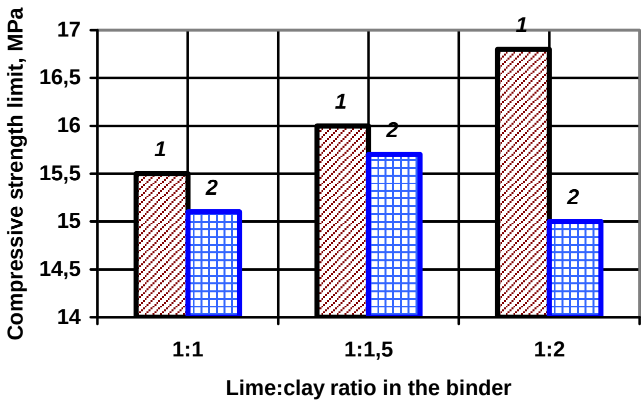


Figure 3. Compressive strength limit of samples based on obtained binder:
1 – based on clay No. 1; 2 – based on clay No. 2;

A more detailed study reveals a lattice of new formations represented by low-basic silicate hydrates.

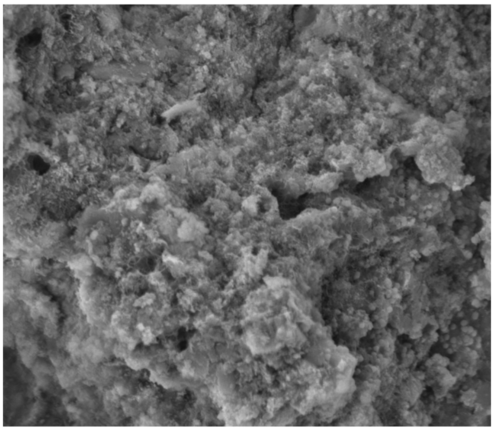


Figure 4. Microstructure of sample based on obtained binder on basis of clay No. 1, composition No. 1: ×5000

Performance characteristics of products are more affected by the molding pressure. For this reason, in order to create high-density material packaging and, as a result, to increase the strength properties of the products, the influence of the molding pressure was studied. Samples were produced with the content of binding component of 15 % from the mass of dry mix. The results of the experiment are shown in Figure 5.

With the increase of the pressure, under which raw brick is formed, from ten to thirty megapascals, product parameters increase from 13.9 MPa to 27 MPa (clay No. 1), and from 14 MPa to 30 MPa (clay No. 2). Improvement of strength properties after increasing the molding pressure from ten to thirty megapascals made up 49 % for the samples based on clay No. 1, and 53 % - for the samples based on clay No. 2. This way, it can be said that increasing the molding pressure presumes the improvement of performance properties of composites.

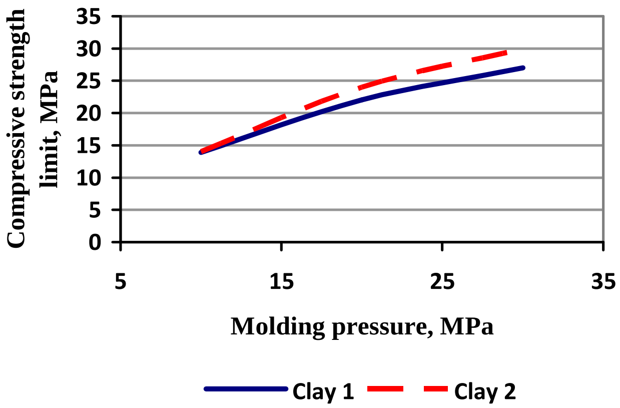
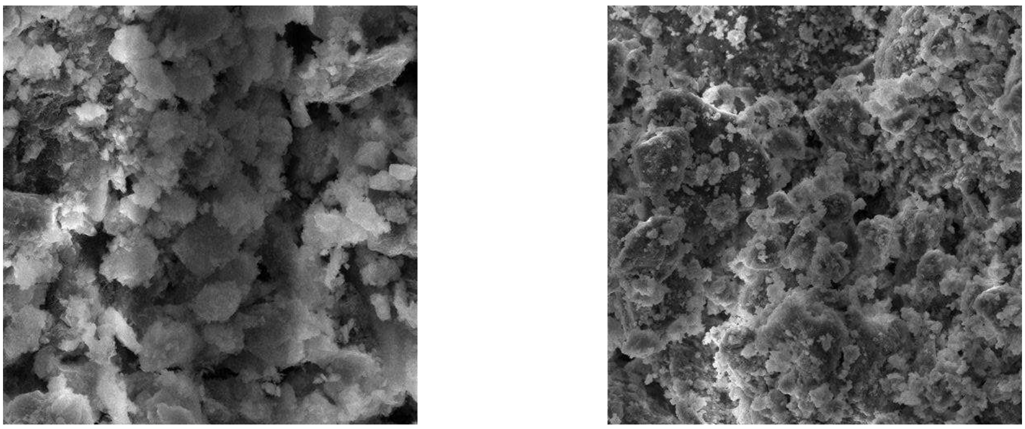


Figure 5. Compressive strength limit values for samples depending on molding pressure.

The research of the influence of molding pressure (from 10 to 30 MPa) on the microstructure (Figure 6) of the composites has shown that there is an observable increase in material packaging density and, as a result, improvement of strength properties.



a b

Figure 6. Microstructure of samples based on clay No. 1, SEM, ×10000: molding pressure, MPa: a – 10; b – 30;

4. Conclusion

This way, use of aluminosilicate raw materials, represented by clay rocks that are unconventional for the building industry, provdes the ability to obtain wall composites that possess high performance properties. Choosing pure quicklime or a specially prepared binder as a binding agent to obtain composites with higher parameters depends on the particular rock used and its composition. Increasing the performance characteristics of the obtained products is possible by changing the molding conditions. For this reason, in order to create high-density material packaging and, as a result, to increase the strength properties of the products, it is reasonable to use higher pressure, under which raw brick is formed, which will facilitate the increase of quality of highly-hollow products.

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References

[1] Loo L S and Gleason K K 2004 *Polymer* **45** 5933–39
[2] Maitil P, Nam1 P H, Okamotol M, Kotaka T, Hasegawa N and Usuki A 2002. *Polymer Engineering & Science* **42(9)** 1864–71
[3] Mollins L H, Stewart D I and Cousens T W 1996 *Clay Minerals* **31** 243–52.
[4] Xiaohui Liu, Qiuju Wu 2001 *Polymer* **42(25)** 10013–19
[5] Gajanan B, Raghavendra R, Hegdel M G, Kamathl and Bhushan Deshpande 2008 *Journal of Engineered Fibers and Fabrics* **3(30)** 22–34
[6] Liu X, Wu Q 2001 *Polymer* **42(25)** 10013–19
[7] Kiliaris P and Papaspyrides C D 2010 *Progress in Polymer Science* **35** 902–58
[8] Suleymanova L A, Kara K A, Suleymanov K A, Pyrvu A V, Netsvet D D and Lukuttsova N P 2013 *Middle East Journal of Scientific Research* **18(10)**1492–98
[9] Kharkhardin A N, Suleimanova L A , Kara K A , Malyukova M V and Kozhukhova N I 2013 *World Applied Sciences Journal* **25(2)** 347–53
[10] Volodchenko A A, Lesovik V S, Volodchenko A N, Zagorodnjuk L H 2015 *International Journal of Applied Engineering Research* **10(24)** 45142–149
[11] Volodchenko A A, Lesovik V S, Volodchenko A N, Glagolev E S, Zagorodnjuk L H, Pukharenko Y V 2016 *International Journal of Pharmacy and Technology* **8(3)** 18856–67