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Improving The Efficiency Of Wall Materials For «Green» Building Through The Use Of Aluminosilicate Raw Materials*

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Abstract- In modern conditions the problems of mining waste usage resulting from the minerals extraction acquire a special urgency. The most rational area for the waste usage is the building materials production. Solving this problem will significantly improve the construction industry technical and economic performance and reduce the waste negative impact on the local ecological systems. Increased mining production by the end of the twentieth century led to the fact that every year we move about 300 billion tons of rocks though use only 5-7% of them. An important direction is the use of the so-called technogenic deposits - accumulated over the past years mining facilities waste. Investigating the rational environmental management, the use of natural and environmentally friendly man-made materials, the introduction of new modern, energy-efficient and resource-saving technologies, aimed at solving urgent problems on a significant increase in production efficiency of new construction composites. The successful development of an effective raw mixture composition using industrial waste can be carried out only on the basis of deep and comprehensive research of physical-chemical and technological hardening processes. Thus the use of non-traditional clay raw materials in the composites production for "Green building" allows you to theoretically justify and experimentally confirm the possibility of transition from the traditional raw material to obtain composite materials based on non-traditional raw materials.

Keywords: "green" composites, aluminosilicate raw materials, wall materials, clay rocks, heat and humidity treatment, structure formation, building materials.

Introduction

One of the main science development directions nowadays are energy saving, rational nature management, innovative technologies for the production of "green" composites development, which is particularly important in construction materials science.

To expand the range of wall materials there it is suggested to use energy saving aluminosilicate raw material with high internal free energy. This raw material specificity lies in significant contrast to the commonly used rocks, mineral composition and structure. Over the last 15-20 years has decreased the amount of exploration work. There is practically no increase of nonmetallic raw materials reserve. In the next 10-20 years we may be left without traditional raw materials of building materials industry.

At the same time there are significant reserves of not used energy-saving raw materials with high internal free energy, the use of which does not require large capital investments.

Modern building materials industry research data analysis allows theoretically justifying and experimentally confirming the structure formation process controlling possibility to produce materials with desired properties by introducing into a raw mass some non-traditional for the construction industry aluminosilicate rocks [1-4].

Rocks of this genetic type are widespread. However, a large proportion does not meet the applicable regulatory requirements to raw materials for the traditional building materials production. At the same time the material composition and the presence of thermodynamically unstable compounds help reduce the energy intensity of obtaining effective new generation building composites. Selecting such raw materials is possible only by taking into account its genesis, structural and textural characteristics and mineral composition.

From the entire range of clay deposits the industry uses only a small fraction, which meets the applicable legal and technical documents. Due to the use of non-traditional clay rocks in wide range of composite binders and walls materials manufacture is possible a transition from the traditional raw material for the production of composites based on non-conventional aluminosilicate rocks. These rocks composition specificity is the presence of thermodynamically unstable compounds such as mixed-minerals, X-ray amorphous phase, dispersed poorly rounded quartz, imperfect structure hydromica, seldom Ca^{2+} montmorillonite and kaolinite. These aluminosilicate materials allow changing the new formation's morphology, providing the cementing compound structure optimization and, accordingly, improve the physical and mechanical properties of autoclaved silicate materials.

Main part

The objective of this paper was wall materials efficiency improving for "Green" building by using aluminosilicate raw materials of different genetic types.

Silicate materials are composites which are formed by reaction of lime with silica binder component under hydrothermal conditions at elevated pressure. As the siliceous component of the traditional technology is used quartz sand, the requirements for which shall be defined by normative documents. As the silica component can be used volcanic rocks, tuff, volcanic sand, as well as screenings of crushing quarzitic sandstone and granite. During autoclaving between traditional raw materials mixture components occurs chemical reaction with the calcium hydrosilicate formation. So the greatest practical importance have CSH(B), $C_2SH(A)$, C_2SH_2, tobermorite $C_5S_6H_{5-2}$ and less often xonotlite C_6S_6H.

Physical and chemical processes that occur during hydrothermal treatment are largely associated with surface phenomena. Ribs, edges and corners have the highest surface energy. In the areas which are the nucleation centers are formed calcium hydrosilicates.

Ingredients dissolving and calcium hydrosilicates synthesis using conventional raw materials takes place at high temperature, which defines the energy consumption increased in the silicate materials production. Reducing energy costs for production can be achieved by using silica-containing materials having high activity, which is defined by a lower temperature of silica dissolution. Selecting such a raw material is possible only by taking into account its genesis, structural and textural characteristics and mineral composition. Geological processes disintegrate the rock, thus, its particles become amorphous and create structural defects, which significantly increases the raw material activity (Fig. 1).

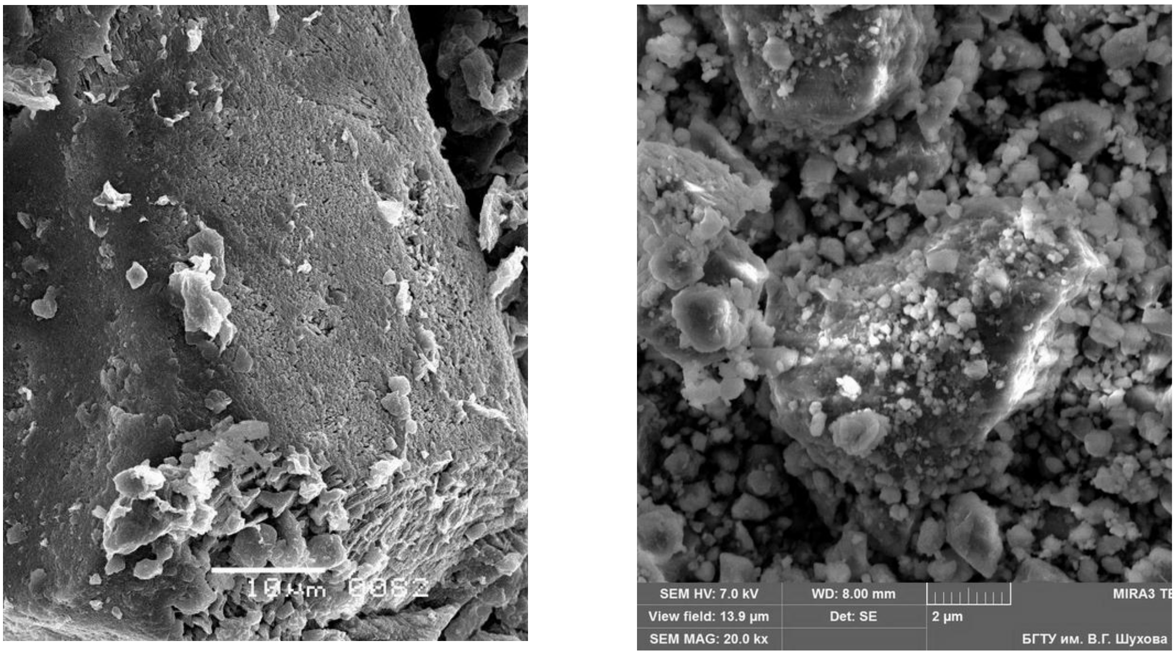


Fig. 1 - The surface of the quartz disintegrated by geological processes

Improving silicate materials physical and mechanical properties and reducing their power consumption can be achieved by obtaining hydrogarnets and other compounds of the $CaO–Al_2O_3–SiO_2–H_2O$ system in the cementing compound composition.

Autoclave raw materials base research data analysis allowed to theoretically justify and experimentally confirm the possibility of controlling new formations synthesis for obtaining materials with desired properties by introducing a raw mass with clay formation unfinished stage clay rocks.

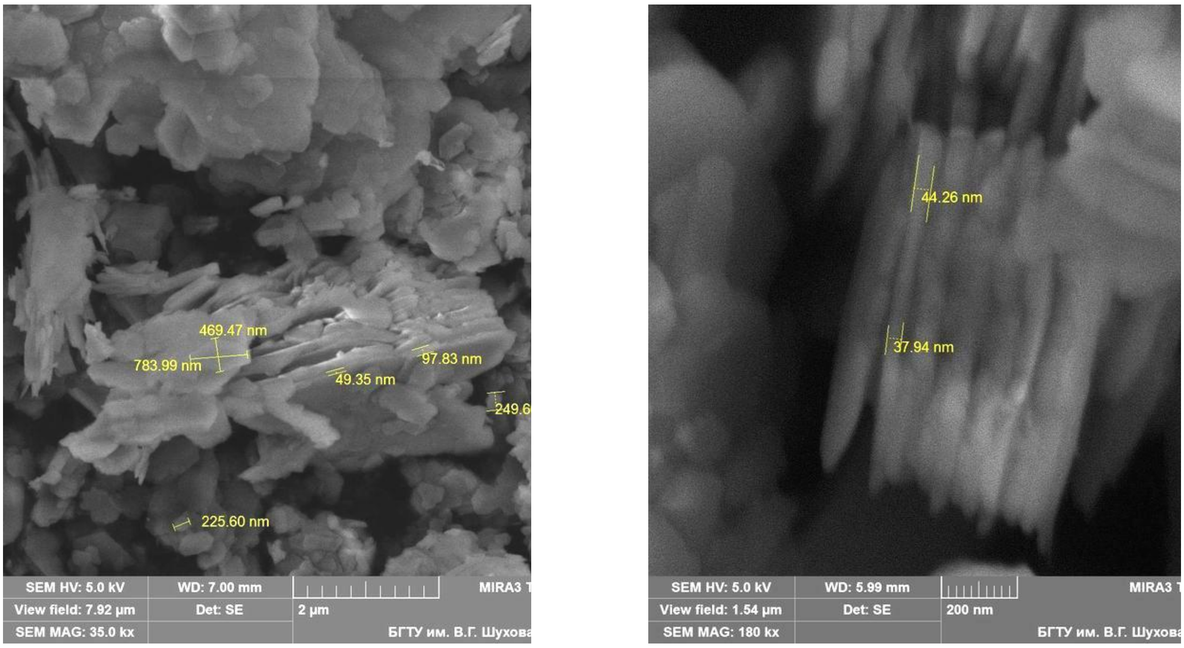
Rock-forming minerals of clay rocks allow changing the crystalline new formations morphology, providing optimization of the cementing compound structure and, accordingly, improve the autoclaved silicate materials physical and mechanical properties.

Clay rocks under incomplete clay formation stage contain highly dispersed components – clay minerals, X-ray amorphous phase and finely dispersed quartz. Quartz surface is heavily corroded. In these locations their crystal structure is most disordered, which, consequently, increases the crystals dissolution process intensity and the silica transition into solution. Natural processes performed the part of the work on the rock destruction, which allows reducing the energy consumption for the binder grinding.

Among rocks having industrial value are the most widely distributed sedimentation zone deposits. This clay rocks are of three genetic types (aeolian-eluvial-talus, marine coastal-lagoon and deluvial). As raw material for silica materials production can be used coarse, rich with fine quartz clay rocks of the diagenesis weathering crust zone, in particular, loam of eolian-eluvial-deluvial genetic types, which are still hardly applied in the construction industry.

Clayey substance has a complex chemical and mineral composition [5-13]. In recent decades, with the use of modern methods of investigation (electron microscopy, x-ray diffraction, infrared spectroscopy) were investigated in detail structures of clay minerals and their properties. It was found that the elementary layers and space between them in the clay system are nano-sized and have highly developed active surface. If you separate the nanocrystals from each other by physical or chemical means, you will receive a universal modifier with the distance between its inserts for about 1 nm (Fig. 2).

Clay minerals nanoparticles, which are contained in large quantities in clay rocks, due to their high physical and chemical activity can be used as highly efficient adsorbents, lubricants for drilling fluids, inorganic plasticizers, and also as a cheap and durable natural material for creation of artificial protective screens against the spread of different contaminants in natural soils.



a) *b*)

Fig. 2 - Layers of clay substance flat crystals, SEM:
a) - × 35000; b) - × 180000
b)

Thus, it can be concluded that by using aluminosilicate rocks of unfinished clay formation stage as a raw material, the composition of which is characterized by presence of a thermodynamically unstable compounds enables to receive effective silicate materials under hydrothermal treatment conditions without pressure [14-20].

For research were used three of the most widespread on the territory of the Kursk magnetic anomaly eolian-eluvial-deluvial Quaternary clay rocks differing in composition and properties. The value of rocks plasticity varies from 6 (sandy loam) to 11.5 (loam № 1 and loam № 2).

Visually the samples are unconsolidated brown rocks. The bulk of the pelitic fractions have pelitomorphic micro scaly structure, unevenly colored by organic matter and iron hydroxides. By particle size composition (Table 1) and the number of plasticity the sandy loam can be described as dusty, and loam №1 and loam №2 as a light dusty. According to particle size distribution and plasticity the sandy loam can be described as dusty and loam № 1 and №2 as light dusty. Chemical composition (Table 2) shows that the rocks have high silica content and are classified as acidic. The rocks contain a large amount of free silica.

Table 1.Grain size distribution composition of sand-clay rocks

Rock	Sieve size, mm					
	< 0.1	0.1 …0.05	0.05 …0.04	0.04 …0.01	0.01… 0.005	> 0.005
	Fraction content, wt. %					
Sandy loam	15.7	12.90	5.82	42.95	5.70	16.93
Loam № 1	0.55	20.72	18.58	21.15	7.49	31.51
Loam № 2	0.2	9.33	9.56	29.86	9.35	41.70

Table 2. The chemical composition of sand and clay rocks

Rock	iO$_2$ general	iO$_2$ ree	l$_2$O$_3$	iO$_2$	e$_2$O$_3$	aO	gO	$_2$O	a$_2$O	.p.p.	otal
Sandy loam	2.87	1.78	.70	.42	.63	.77	.03	.26	.10	.05	9.83
Loam № 1	3.0	8.05	0.4	.72	.60	.32	.32	.86	.29	.95	8.46
Loam № 2	5.1	5.12	2.5	.77	.36	.21	.64	.93	.74	.76	7.01

Polymineral composition of the investigated sand-clay rocks, which are natural nanodispersed raw materials and their thermodynamic instability determines the possibility of interaction with lime resulting in the formation of cementing compounds under hydrothermal treatment without pressure and, accordingly, receiving silicate wall materials with low energy consumption.

As the calcareous component was used lump quicklime JSC "Stroimaterialy" (Belgorod). Lime activity amounted to 78.3 %, the quenching temperature was 97.5°C, the time of quenching – 4 min 30 sec.

Samples were prepared by dry pressing. Pre-ground limestone and the original rock was mixed at a predetermined ratio, moistened with the necessary amount of water and kept in a sealed cup until completely hydrated lime. The samples were steamed at 90-95°C for 12 hours.

As a binder was used ground lime and lime-sand-clay binder (LSCB), obtained by joint grinding of lime and rock. The ratio “lime : sand loam” in LSCB was 1 : 2, the specific surface area was 7700 m^2/kg. The raw material mixture was prepared by mixing the binder used with the original rock. The lime content of the raw mixtures varied from 4 to 14 wt. %. Samples were molded from the raw material mixture of 10% moisture at a compression pressure of 20 MPa, which is widely accepted in the traditional technology of silicate bricks.

The raw strength on the lime-sand (control) mix basis amounted to 0.43 MPa. Using sand-clay rocks as a siliceous component significantly increases the strength of the raw, and with the lime content increase the strength grows either (Fig. 3).

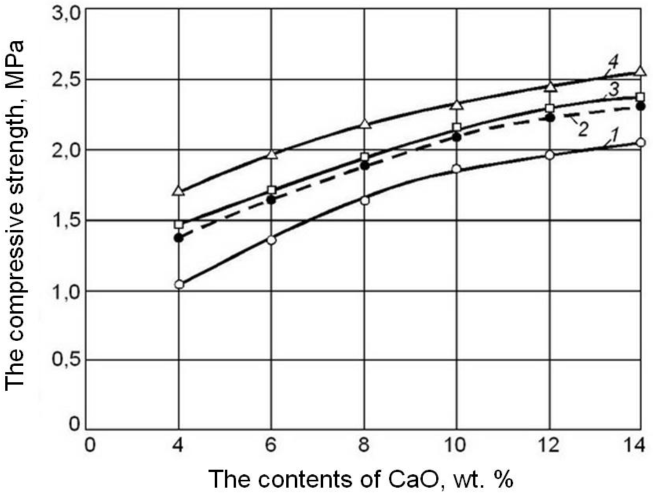


Fig. 3 - Effect of lime composition on the strength of the raw. Rock: *1, 2* – sandy loam; *3* – loam №1; *4* – loam №2; binding: *1, 3, 4* – lime; *2* – LSCB

Using sandy loam as a siliceous component with lime content of 10 wt. % allows obtaining the raw strength of 1.85 MPa, which is higher than strength of the control samples by 4.3 times (Fig. 3, curve 1). The raw strength on the basis of LSCB (the lime content of 10 wt. %) increased 4.9 times (Fig. 3, curve 2).

Loams provide higher strength raw than the sandy loam (Fig. 3, curves 3 and 4). This is due to high content of pelitic fraction. To increase the strength of loamы №1 and №2, with the lime content of 10 wt. %, respectively, in 5.1 and 5.5 times.

For raw mixtures with lime content of 10 wt. % there was studied the influence of compression pressure on the strength of raw (Fig. 4).

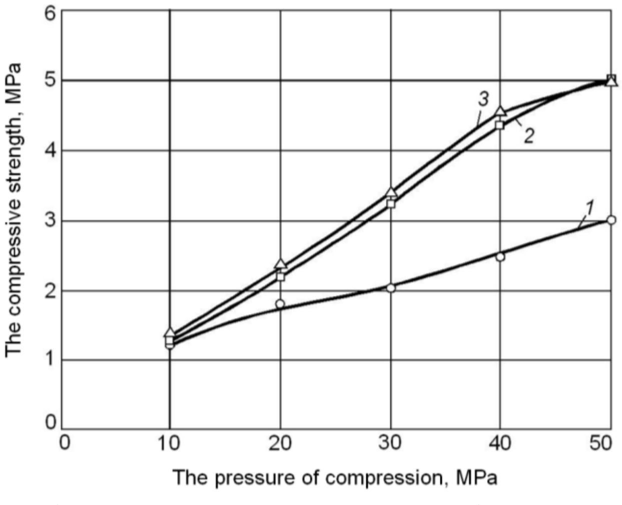


Fig. 4 - Impact of compaction pressure on the strength of the raw *1*— sandy loam; *2* — loam №1; *3* — loam №2

The effect of compression pressure on the strength of raw depends on the sandy-clay rocks type. Raw strength is obtained at a compression pressure of 10 MPa, almost the same for all sand-clay rocks and is equal to1.2…1.38 MPa. With increasing compaction pressure up to 50 MPa, raw strength, based on the sandy loam, increases up to 3 MPa, which is higher than the strength of lime-sand in 7 times (Fig. 4, curve 1). Considerably greater impact the increase in the pressure has on the growth of raw strength based on the loam. The change in strength character and its value for loams №1 and №2 are about the same (Fig. 4, curves 2 and 3). Raw strength is raised up to 5 MPa, i.e. in 11 times. It can be concluded that the increase in compaction pressure has the greater effect on increasing the strength of the raw, the higher the pelitic fraction content in the rock.

During raw compaction under the pressure there occurs raw material mixture particles convergence by reducing its original voidness. The main condition of the mixture compaction is the uniform distribution of different sizes grains in it. In the compacted silicate mixture simultaneously act the capillary pressure forces, mechanical gearing and molecular adhesion. The main factor is the capillary pressure, which in the total share of influence on the raw strength is more than 80 %.

Capillary pressure depends on the content of fine particles in the composite and, mainly, on colloidal dimensions particles. In terms silicate materials real production on the basis of traditional lime-sand raw material mixture it is difficult to obtain a binder containing particles of colloidal size, whereby the raw has a low strength. Increasing the time of grinding increases energy production, but it has little impact on the raw strength increase.

A significant increase in the raw strength on the basis of sand-clay rocks is due to the presence of fine particles, including nanosized clay minerals. These filling the voids particles compact the composite structure. Liquid tension in the remaining smallest capillaries, formed by the convergence of mixes dispersed particles, creates a very large specific pressure resulting in increased raw strength. With increasing compaction pressures there reduces the capillaries size and, therefore, increase the capillary forces.

Increasing the compaction pressure has a significant impact not only on increasing the strength of the raw but also ready products.

The greatest strength is gained in samples at lime content of 10 wt. %. Further increase in lime content causes reduced strength. Obviously, the content of 10 wt. % CaO in sandy loam is optimal for the formation of a rational composition of new formations under given hydrothermal treatment conditions. Optimal molding humidity is 10 %. At higher humidity during the samples pressing emits water.

With increasing compaction pressure from 10 to 50 MPa the strength of the products (Cao content of 10 wt. %) increases from 17 MPa to 32 MPa. The increase in strength with increasing compaction pressure from 10 to 30 MPa was 67 %, and from 30 to 50 MPa – 33 %. It can be concluded that the most effective is the compaction pressure increasing up to 30 MPa.

The investigations of microstructure were performed on samples molded at a compression pressure of 10, 20 and 50 MPa. With increasing compaction pressure is observed the increase in the material’s packing density, resulting in increased strength (Fig. 5).

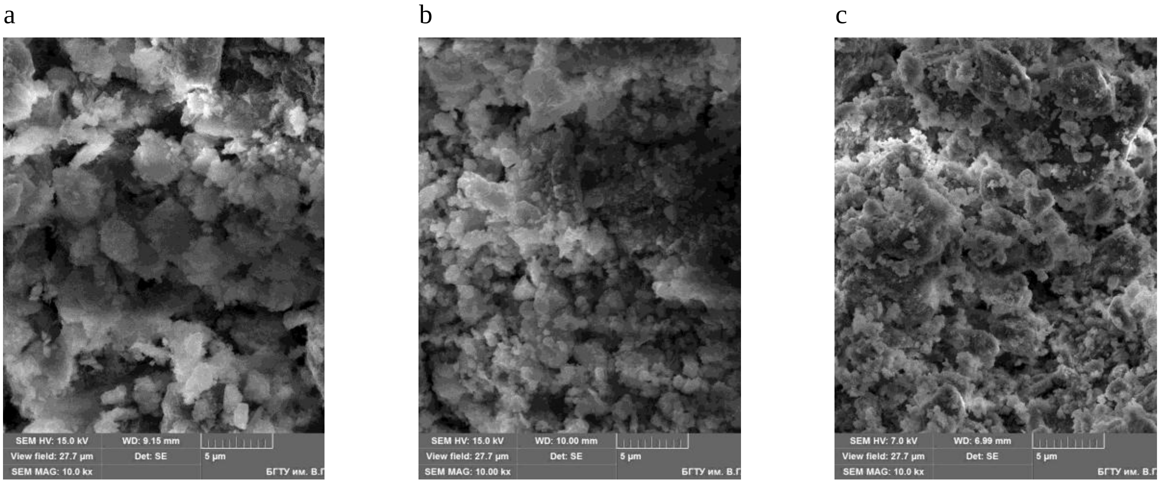


Fig. 5 - The microstructure of the samples based on loam №1, SEM: × 10000:
pressing pressure, MPa: a – 10; b – 20; c – 50

According to the data of differential thermal new formation there are represented mainly poorly crystallized calcium silicate compounds. Endothermic effect in the temperature range of 100-200 °C and exothermic effects at 900 and 940 °C indicate the presence of poorly crystalized calcium low basic hydrosilicates (Fig. 6).

a

b

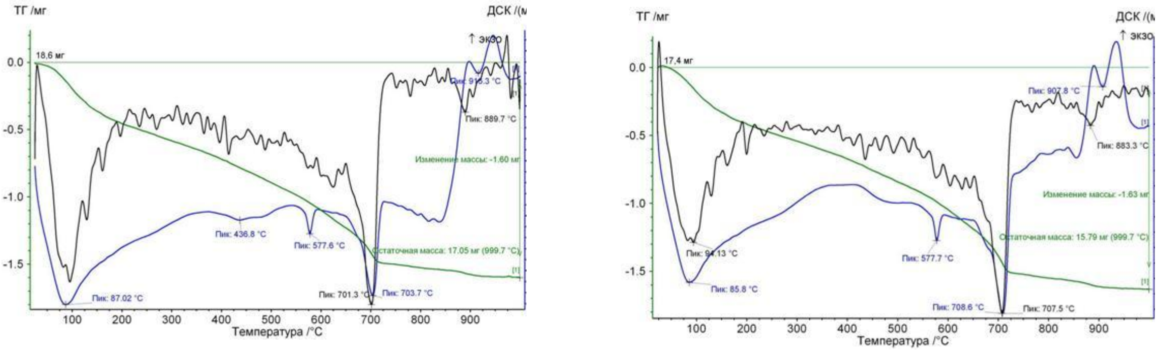


Fig. 6. Derivatograms of samples on the basis of loam:
a – loam №1; b – loam №2

The endothermic effect at 577°C is associated with quartz polymorphic transformation. In the temperature range of 400-500°C there is a slight endothermic effect, which can be attributed to the loss of constitutional water of unchanged clay minerals. The endothermic effect at 700°C is due to the destruction of carbonate containing new formation. At this temperature is also recorded the weight loss due to carbon dioxide emissions.

On the derivatograms there are no effects on calcium hydroxide dehydration. This indicates that lime completely reacted with the studied materials' rock-forming minerals.

Summary

When using non-traditional clay rocks for the synthesis of "green" composites there is formed solid microstructure of cementitious material to form poorly crystalized low basis calcium hydrosilicates of water main calcium carbosilicate of indicative composition $CaSiO_3 \cdot CaCO_3 \cdot Ca(OH)_2 \cdot nH_2O$ and hydrogarnets, which leads to a strong material condensation-crystal and crystal structure provides silicate products high physical and mechanical properties.

Conclusion

On the basis of non-traditional clay material used as an organic plasticizer can be obtained efficient, energy-saving high-hollow painted wall building materials with low energy consumption. The possibility of synthesis in the system $CaO–SiO_2–Al_2O_3–H_2O$ new formations without traditionally used worldwide autoclaving at 0.8-1.2 MPa.

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