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Theoretical backgrounds of non-tempered materials production based on new raw materials

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Abstract. One of the trends in construction material science is development and implementation of highly effective finish materials which improve architectural exterior of cities. Silicate materials widely-used in the construction today have rather low decorative properties. Different coloring agents are used in order to produce competitive materials, but due to the peculiarities of the production, process very strict specifications are applied to them. The use of industrial wastes or variety of rock materials as coloring agents is of great interest nowadays. The article shows that clay rock can be used as raw material in production of finish materials of non-autoclaved solidification. This raw material due to its material composition actively interacts with cementing component in steam treatment at 90–95 ºC with formation of cementing joints that form a firm coagulative-cristalized and crystallization structure of material providing high physic-mechanical properties of silicate goods. It is determined that energy-saving, colored finish materials with compression strength up to 16 MPa can be produced from clay rocks.

1. Introduction

Energy-saving, efficient use of natural resources, process technologies and innovations in ecological composite materials production are the main trends in constructional material science today. To broaden the nomenclature of silicate wall- and finish- materials, energy-saving non-traditional aluminosilicate materials with high available internal energy can be used. Clay rock materials significantly differ from traditionally used rock materials by the mineral composition and the construction [1-3]. These materials are widely spread. But a significant number of these materials do not meet the requrements of state standards to the traditional raw materials used in construction materials production. At the same time, material composition and thermodinamically-unstable bounds allow one to lower power requirements for production of effective composite construction materials of new generation. These raw-materials can be chosen only according to their origin, structure-textural features and mineral composition [4-6].

Design qualities of finish materials are very important. Using different raw materials and additives, one can produce wall-finish materials of different colors. Nowadays there is a broad nomenclature of coloring additives, but due to the requirements to the autoclaved silicate materials production, only a minor part of them can be used.

That is why the use of industrial wastes and clay rocks as coloring agents in production is of great interest. These ways of silicate materials coloring give a necessary color to the product and allow producing materials with high performance.

Materials investigated in this article were of light-brown color. Energy-saving wall and finish materials made of these raw materials have brown and light-brown color. The color does not change with time and in steaming. Also, unlike autoclave treatment, high-pressure steaming does not have negative impact on the coloring agents in rock materials.

2. Materials and methods

Portlandcement of ZAO "Eurocement" State Standard 31108–2003, unslaked lump lime of JSC "Belgorodstroimaterialy" State standard 9179–77 were used as a cementing component. Aeolian-sedentary-diluvial clay materials of the Quaternary Period of Kursk Magnetic Anomaly deposits were used in the work.

MicroSizer 201 was used to determine the grain-size composition of materials as it allows determining the grains from 0.2 to 600 mkm in size.

To investigate the mineral composition of raw materials and synthetically produced formations, X-ray phase analysis method was used. The research was conducted with the help of X-ray diffraction meter ARL X'TRA. Thermo Fisher Scientific. Besides, differential thermal analysis was used to identify mineral composition and new formation products. The research was conducted with apparatus Derivatograph Q – 1500 D. Scanning electron microscopy (SEM) was done with the help of MIRA 3 LM microscope.

The workpieces production method depends on the composition of raw mixture. If only unslaked groud lime was used as a cementing component, the raw materials were mixed in necessary proportions.

The mixture with a cementing component (clay rock and a cementing component which were ground in advance) was added to the base material or to the silica containing component of the same composition and was mixed with water. After formation, the workpieces were put into the steam curing chamber and were steam-treated at 90–95 °C degrees according to the scheme: 1,5 h.+9h. +1,5h.

3. Main part

Wall and finish materials for exterior and interior must be highly resistant to the influence of the environment, especially if clay rocks are used as main components. The main task to solve in production of clay rocks materials of different origin is making them durable [7,8].

So the requirements to the raw material for wall and finish materials production are:

– the produced composite (wall or finish material) after the period of strength development and structuring, must have such a persistent quality which provides resistence to the environment without cracks formation, deflection etc, exceeding permited values;

– resistant to internal stresses caused by outer factors (swelling due to moisture atack) for a long period of time, must preserve the structures in long-time influence of different outer factors;

– finish materials should keep their fasade and surface finish for a long period of time;

– exterior finish materials must be highly resistant to weather impact.

The purpose of the work is to develop technology of non-tempered clay finish materials production from clay of different origin.

Aeolian-sedentary-diluvial clay materials of the Quaternary Period Kursk Magnetic Anomaly (KMA) are the most common on the territory of Kursk Magnetic Anomaly. Most of them do not meet the requirements to the raw materials for cement and ceramic goods production, but due to their physical composition they can be used in the production of silicate materials. That is why these rock materials were used for study.

The most representative sandy and clay rocks which differ in composition and properties were used in the research. Particles distribution according to their size is shown in tables 1 – 3.

Table 1. Grain-size composition of clay rock № 1

Fracture content, mas. %, sieve size, mm					
More than 0.1	0.1–0.05	0.05–0.04	0.04–0.01	0.01–0.005	Less than 0.005
14.7	11.8	4.82	44	6.7	17

Table 2. Grain-size composition of clay rock № 2

Fracture content, mas. %, sieve size, mm					
More than 0.1	0.1–0.05	0.05–0.04	0.04–0.01	0.01–0.005	Less than 0.005
0.4	18.72	18	22.15	8.5	34.15

Table 3 Grain-size composition of clay rock № 3

Fracture content, mas. %, sieve size, mm					
More than 0.1	0.1–0.05	0.05–0.04	0.04–0.01	0.01–0.005	Less than 0.005
0.19	8.33	9	27.5	8.65	44.7

The investigated material is friable rock of brownish color with organic substances. Clay rocks № 1 and № 2 have the plasticity index 7,5 and 11, while clay rock № 3 has that one of 14.
Clay rocks are mixed-layer formations of X-ray amorphous phase with the traces of hydromicas, Ca^{2+} montrominolites and kaolinite.

The polymineral composition of the investigated clay rocks, and their thermodynamic instability determines their interaction with lime and formation of cementing joints during hydrotermal treatment without pressure, and producing wall and finish silicate materials during low energy consumption [9, 10].

The workpieces for the investigation were produces by moulding. The ammount of unslacked lime was 5–25 % of the dry mixture mass. The wetness of raw mixture depends on its composition (30-40 %). After keeping in normal conditions, the mixture was formed and the workpieces were addtionally dried at 45–50 °C till 12–14 % dampness. It was necessary to minimize spoilt production during hydrothermal treatment. To increase the quality of the clay composites, reinforcing fibers were added into the composites. The ammount of polypropylene fibre was 0.5 and 1 %.

Experiment results are shown in figure 1.

The workpieces made of clay rock № 1 with the amount of reinforcing fibers 1 % have the highest strength of 8.2 MPa with the cementing component of 15 % from the mass of the dry mixture (figure 1, *clay rock № 1*).

Strength properties of workpieces made of clay rock № 2 (figure 1, *clay rock № 2*) with the amount of reinforcing fibers equal to 1 % have 7.3 MPa strength. The workpieces with the amount of the cementing component (unslucked lime) equal to 15 % of the dry mixture have high water resistance (softening coefficient 0.81).

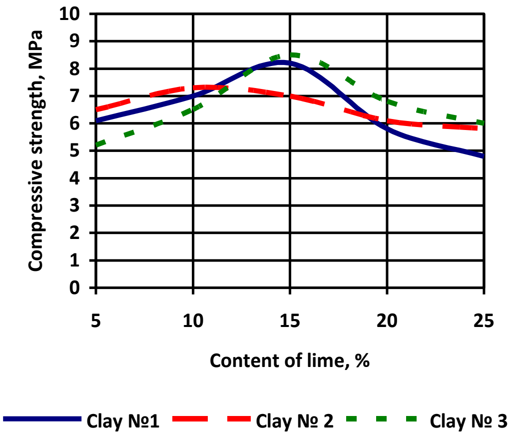

Figure 1. Pressure resistance of workpieces depending on cementing content, fibre content 1%

The workpieces made of clay rock № 3 have the highest strength parameter (8.5 MPa) (figure 1, *clay rock № 3*) with the amount of reinforcing fibers equal to 1 %. These workpieces have the best water resistance (softening coefficient 1).

If one compares the parameters of compression resistance of the workpieces with reinforcing fibres with those without them, one can say that reinforcing fibres in the amount of 1 % of the dry mixture mass increases the qualities of material 3 times, which determines the durability of the composites.

The workpiece microstructure made of clay Mascat № 1 with reinforcing fibre 1 % and 15 mas.% CaO was investigated with the help of the raster-type electronic microscope (figures 2-3).

The structure of the composites is friable due to the high humidity of the raw mixture. There are a lot of pores. Reinforcing fibres in the amount less than 1% significatly increases the characteristics of the composites due to the tight coehision of fibers and cementing component (figure 3).

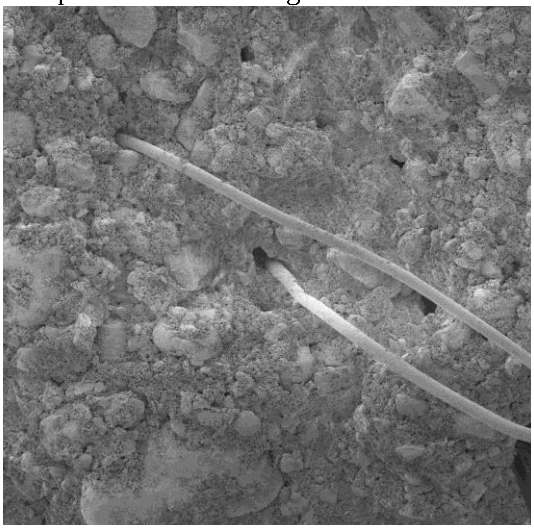

Figure 2. Workpiece microstructure with microfibre content with 1 % and 15 mas.% CaO

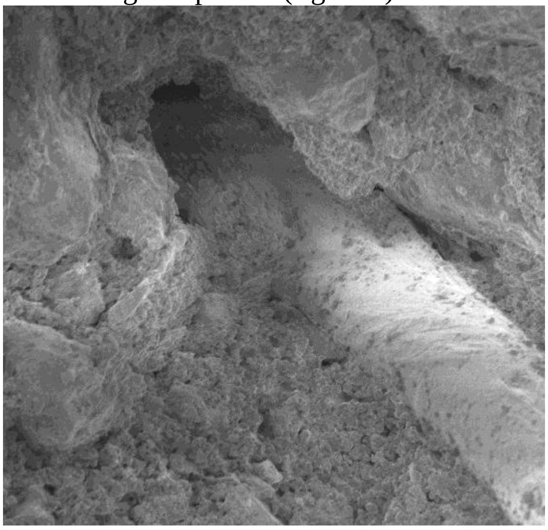

Figure 3. Fiber and composite contact zone (15 mas.% CaO)

The use of reinforcing fibres in constructing composites improves their service properties. The choice of the reinforcing fibre depends on the required properties that one wants to obtain. But it is not advisable to use metal fibre to lessen the weight of the workpieces.

To increase the growth of new formations and close-packed arrangement, a number of tests were conducted in order to determine the influence of content and a kind of the cementing component on the properties of the composites. As it was described above, reinforcing fibres improve the qualities of the composites. In order to choose the best composition for the production, the qualities of the workpoieces made of the portland cement cementing component, lime and reinforcing fibres were studied. Experiment results are shown in table 4 and in figure 2 and 3.

Table 4. Physical-mechanical properties of clay silicate materials № 2 depending on portland cement contents with 5 mas. % CaO and 1 % mas. with polypropylene fiber

Physical-mechanical properties	Cement content, mas. %			
	5	10	15	20
Compression resistance, MPa	9	12,6	13.5	16.2
Softening coefficient	0.7	0.85	0.9	1
Average density, kg/m3	1385	1445	1455	1450
Water absorption, %	21.23	23.54	23.24	15.57

4. Conclusion

Clay rocks not common for the construction may be used in the production of non-tempered finish materials with good atmospheric resistence qualities. The use of unslacked lump lime or a specially prepared cementing mixture in order to increase the properties of materials depends on the kind of clay rock used in the production process and their composition.

The increase of material service properties is possible due to the use of the amount of reinforcing fibres. It is advisable to use different kinds of fibres to obtain composites of high quality. The choice of fiber material will depend on the required properties.

The use of the optimal composition will result in new formations of better quality that will help to obtain high quality materials. The choice of the cementing component depends on the required qualities and desired price of the final product.

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