Decreasing of energy expenditures connected with production of fiber cement panels for building finish

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Abstract. The results of studies of the decreasing of energy expenditures connected with production of fiber cement panels (FCP) on the base of cellulosic fibers used as a facing material in hinged ventilated facades by means of the increase activity of raw components are presented in the article. The application of the FCP in building construction and heat insulation of redeveloped buildings allows to increase their energy efficiency.

1. Introduction

At the present time, many federal, regional and municipal programs in the construction and housing and public utilities are being implemented in the Republic of Tatarstan [1–4], that seek to improving energy efficiency and energy saving of buildings and facilities, liveable for citizens, ensuring the growing need for a comfortable, safe, ecological, durable and inexpensive housing. The growth of new construction output, reconstruction and capital repairs of existing buildings in Russian Federation creates increased needs for expanding production and the use of durable, environmentally friendly finishing and aesthetically attractive finishing materials, including for ventilated facades, and for interior decoration of buildings. In turn, as the practice of construction shows the best indicators for the cost and material consumption in these segments of the use of products have a FCP (Figure 1). By cost and manufacturability of use in construction, they successfully compete with ceramic granite, aluminum panels, plates from polymeric materials, etc.

Traditional technology for the production of FCP is the fibrillation of a fibrous material, including asbestos, mixing it with binders and water, molding products, preliminary and final hardening and machining. The products received to date are not fully the most effective for the criteria of the complex of operational properties, longevity and energy costs for production. The end-products are not the most effective for the criteria of the complex of operational properties, longevity and energy costs for production. The current level of development of cement-fiber composite materials and methods of their production do not allow for the significant improvement of operational properties of products exclusively by technological methods without multi-factor approach to the selection of raw materials, modifying additives, the degree and consistency of reprocessing components, manufacturing and hardening modes. Therefore, to more fully utilize production capacity, namely, to obtain environmentally friendly, high performance materials and durable products while a decline in the energy intensity of production and a low production cost, the author carries out numerous experimental studies. In earlier works [5, 6] the influence of various types of mineral and chemical additives on properties of binders and fibrous products based on them, role of dispersed reinforcement in the formation of their structure and properties was studied [7]. This made it possible to obtain compositions of mixtures [8],...
organo-mineral modifiers [9] that significantly improve the operational properties of products and indices of resistance in relation to external influences of the environment.

2. Materials and Methods

As a raw material were used portland cement, ground glass sand (SUd=310m2/kg), pulp as a fiber material, active mineral additive - kaolin (SUd = 1357m2 / kg), flocking addictive with high level of ion charge and water. This article presents results of experimental research on lower energy costs in the manufacture of FCP by increasing the activity of the raw materials. The aim is to establish a regime of hydrothermal treatment of activated FCP with maximum energy-saving ensuring manufacture of products with high bending resistance. Control of modes of hydrothermal treatment was carried out by TPM-200 thermoregulatory manufactured by "OVEN" equipped with a starter and a thermocouple. The test of FCP was carried out under requirements of GOST 8747-88. In the first stage, the activity of the mineral raw material (kaolin) increased through thermal and acid activation.

Heat treatment of kaolin at temperature 550-600 °C considerably increases its hydraulic activity by 545 mg / g (78.6%) while met kaolin is formed, which was proved through measurements of infrared spectroscopy. The optimal soak period at a temperature 600 ° C as shown by experimental studies was 30 min (Table 1).

| Heat treatment time, min | Activity, mg/g |
|-------------------------|---------------|
| 0                       | 693           |
| 30                      | 1139          |
| 60                      | 1238          |
| 90                      | 1133          |

Further activation of obtained metakaolin (600 ° C) was carried out by treatment with aqueous caustic of formic acid and acetic acid at a mass ratio T: F = 1: 1. The amount of acid ranged from 1.0 to 6.0 weight percent.

The activation of metakaolin with a 3% solution of formic acid is the most effective. Hydraulic activity is increased by 100 mg / g.

In the second stage, the features of the influence of thermal and acid activation regimes of kaolin on its phase composition by infrared spectroscopy were studied.
As can be seen from the results of infrared spectroscopy of metakaolin treated with solutions of formic acid in the range of wave numbers from 3600 to 2900 cm$^{-1}$ meeting to stretching of fix OH groups and in the range of wave numbers 1651-1644 cm$^{-1}$ there is a sharp increase in the band intensity (Table 2). On the other hand, the relative intensity of the peaks in the frequency ranges from 913 to 912 and from 1032 to 1029 cm$^{-1}$ responsible for perturbations of oxygen-containing Si-O group and bond in the octahedral layers of Al$^3+$ with O2- and OH-, decreases 1.6-2.3 times. Of special interest is the appearance in Infra-red spectrum of treated metakaolin with solutions of formic acid and a peak in the range of wave numbers from 2146 to 2144 cm$^{-1}$, which quite possibly refers to the formation of a Si-H bond system.

Characteristically, with an increase in concentration of formic acid in the system from 1 to 3 wt. % intensity of this absorption band is doubled, which is probably due to the partial destruction of aluminosilicate under the influence of formic acid. Presumably, in process of formation of a solvate shell on the particle surface of solid phase the amount of bound OH groups is substantially increased and the formation of Si-H bonds is also possible. Thus, treatment of kaolin with acetic acid allows to increase the amount of bound OH-groups. In our view, it may lead to the formation of Si-H bond.

**Table 2.** Comparative characteristic of vibration motion of functional groups of metakaolin activated with formic acid

| Concentration of formic acid, % | The relative intensity of absorption * (conventional unit) at the wave number $\nu$, cm$^{-1}$ |  |
|--------------------------------|--------------------------------------------------|--|
|                               | from 3600 to 2900                                 | from 2146 to 2144 | from 1651 to 1644 | from 1032 to 1029 | from 913 to 912 |
| 0.0                            | 0.24                                              | 0                | 0.42             | 2.3             | 1.62            |
| 1.0                            | 0.91                                              | 0.47             | 0.92             | 1.06            | 1.03            |
| 3.0                            | 1.00                                              | 1.00             | 1.00             | 1.00            | 1.00            |
| 6.0                            | 0.70                                              | 0.89             | 0.88             | 1.46            | 1.14            |

* For the conventional unit, the intensity of the absorption band is taken at a concentration of the solution of formic acid 3.0%.

3. **Results and Discussion**

In the third stage, for validation of our assumptions on lower energy costs in the production of FCP with activated mineral ingredient and in order to determine the optimal regimes for hydrothermal treatment of modified FCPs, we carried out experimental research. Optimization of hydrothermal processing of the FCP was performed by implementing a three-factor design of the second order on the tesseract. As initial independent variables are determined the temperature rise rate ($X_1$) (87.5-116.7 °C / h), duration of isothermal aging ($X_2$) (4-8 hours), cooling rate ($X_3$) (87.5-116.7 °C / h).

As a response, the bending resistance of autoclaved FCP was chosen. Figure 6-8 show a graphical interpretation of the results of mathematical model. With an increase in the time of isothermal aging and a decrease in the cool down rate, the strength of the FCP is observed to increase. The reduction in regime of hydrothermal treatment, namely, a simultaneous reduction of the isothermal soak period to 5 h and an increase in the thermal response in the autoclave to 87.5 °C / hr, does not significantly influence on the physical and mechanical properties of FCP (Figure 2-4).
FCP items obtained by the optimal hydrothermal treatment were tested for water absorption, resistance to frost, shrinkage / swelling deformation, air resistance, water resistance and temperature conductivity. It was found that shortening of the duration of hydrothermal treatment in the recommended intervals does not lead to a decrease in the investigated operating ability of the FCP.

4. Conclusions
The performed research shown that the complex of thermal and chemical activation of mineral raw materials allows to increase its hydraulic activity in 1.78 and 1.93 times. It makes it possible to shorten the duration of hydrothermal treatment by 4 hours and reduce energy costs by 20% while ensuring high performance properties of products (bending value 27.5 MPa, temperature conductivity 0.22 W / m °C, shrinkage 0.2 mm / m, resistance to frost - 250 cycles, air resistance - 300 cycles, impact resilience - 2.5 kJ / m2, water absorption - 3%, coefficient of fastness to water- 0.95). It has been established that directed modification of the system of structural characteristics is achieved by regulating the formulation and technological factors (including the composition of the mixture with mineral and chemical additives, heating rate, isothermal aging time and cool down rate). It is possible to realize production of proposed FCP at enterprises producing asbestos-cement products with the maximum use of existing equipment as well as to organize new production including using the existing technical base of the enterprises of the construction industry of Republic of Tatarstan. The presence of own production of cement-fiber materials on the territory of Republic of Tatarstan will make it possible to fill the need for inexpensive, environmentally friendly, energy-efficient, durable and aesthetically attractive finishing materials using local raw materials. The use of FCP in the construction of new buildings and thermal insulation.
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