ИССЛЕДОВАНИЕ ВОЗМОЖНОСТИ УТИЛИЗАЦИИ ВОЛОКНИСТОЙ МАССЫ ПРИ ПРОИЗВОДСТВЕ СТРОИТЕЛЬНЫХ МАТЕРИАЛОВ

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STUDY OF THE POSSIBILITY OF RECYCLING FIBER MASS IN THE PRODUCTION OF CONSTRUCTION MATERIALS

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АННОТАЦИЯ

В статье приведены результаты экспериментальных исследований по утилизации волокнистой массы в производстве с органоминеральной добавкой в гипсокартонных изделиях. Которое в качестве исходных сырьевых материалов использовали гипсовое вяжущее (строительный гипс) и волокнистую массу хлопкоочистительного производства. Использование волокнистой массы в строительных материалах является перспективным направлением переработки отходов и способствует развитию экологически безопасных технологий.

ABSTRACT

The article presents the results of experimental studies on the utilization of fibrous mass in production with organomineral additives in gypsum board products. Which used gypsum binder (construction gypsum) and fibrous mass from cotton ginning as initial raw materials. The use of fibrous pulp in building materials is a promising area of waste recycling and contributes to the development of environmentally friendly technologies.

Ключевые слова: волокнистые массы, строительный гипс, Технический гипс, гипсокартон, органоминеральная добавка.

Keywords: fibrous masses, construction gypsum, technical gypsum, drywall, organomineral additive.

The most common building components made from gypsum binders include partition panels, partition boards, and gypsum sheathing sheets (dry plaster). These parts are made primarily from construction gypsum, the most common gypsum binder. Gypsum plasterboard, or gypsum dry plaster, is a sheet finishing material made from building gypsum, reinforced with vegetable fiber and covered on both sides with cardboard [1].

In the production of dry plaster, substances are also used that regulate the setting time (gypsum dihydrate, table salt, SDB), additives that lighten the weight of sheets and reduce the consumption of binder (wood sawdust, fiber) ; foaming agents (casein + saponified rosin, caustic soda); adhesives that promote the adhesion of cardboard to the gypsum core (dextrin, casein glue, soluble glass), and adhesives for gluing cardboard edges [2].

Dry plaster is used for interior wall and ceiling finishing by bonding it with special mastics. The joints between the sheets are sealed with shrinkage-free putty. In areas where gypsum is a local material and other effective wall materials are unavailable, gypsum concrete is used to make exterior wall blocks for buildings of categories III and IV. Gypsum concrete blocks are produced in three grades based on compressive strength—M35, 50, and 75—and with frost resistance of at least Mrz.15. Fire protection products for cladding metal structures, elevator shafts, etc. are also manufactured from gypsum and gypsum concrete with lightweight fillers [3].

During the tests on the use of fibrous mass of organomineral additive in gypsum board products, gypsum binder (building gypsum) and fibrous mass from cotton ginning production were used as initial raw materials. Gypsum binders are usually called finely ground products of heat treatment of natural or artificial varieties of calcium sulfate, which, when mixed with water, are capable of setting, hardening and turning into artificial stone in the air. Gypsum binders are classified into low-temperature calcined binders, produced at calcination temperatures of 140–180 °C, and high-temperature calcined binders, produced at 600–900 °C. Low-temperature calcined binders include building gypsum, molding gypsum, medical gypsum, and technical gypsum. High-temperature calcined binders include gypsum–anhydrite cement and high-temperature calcined gypsum, also known as estrich gypsum [4].

Technical gypsum is one of the components of blended binders, which are composite materials consisting of calcium sulfate hemihydrate, Portland cement, pozzolanic additives, or granulated blast-furnace slag. It also serves as a principal raw material for the manufacture of high-strength building products. Low-temperature calcined gypsum binders are products obtained by the partial dehydration of gypsum stone, $CaSO_4 \cdot 0.5H_2O$ [5].

A sample of gypsum binder selected for testing as a component of gypsum plasterboard products was tested in accordance with the requirements of GOST 23789-79. The results of the physical and mechanical tests showed that, based on its compressive strength of 72 kgf/cm² and flexural strength of 35.4 kgf/cm², the gypsum binder sample corresponds to grade G-7. According to its setting time—an initial setting time of 10 min and a final setting time of 28 min—the tested gypsum binder sample is classified as a normal-setting binder [6].

The residue of the gypsum binder on a No. 02 mesh sieve was 6.4%; therefore, the sample was classified as a medium-ground binder. The technological characteristics of the gypsum binder were classified in accordance with GOST 125-79 [7].

The high quality of the gypsum binder, as indicated by the physicochemical test data, was further supported by the results of X-ray phase analysis. The X-ray diffraction pattern of the gypsum binder (Figure X) showed only diffraction reflections characteristic of calcium sulfate hemihydrate at interplanar spacings of 0.588, 0.349, 0.297, 0.279, 0.212, and 0.186 nm. The absence of reflections corresponding to other crystalline phases indicates a high degree of phase purity of the binder. A sample of the fibrous material selected for testing as an organomineral additive to the gypsum mixture was investigated using physical-mechanical, physicochemical, and chemical analysis methods.

To determine the particle-size distribution, the initial fibrous-mass sample was fractionated using KSI-type sieves with aperture sizes of 20, 10, 5, 2.5, 1.25, and 0.63 mm. The results are presented in Table 1.Table 1. Particle-size distribution of the fibrous-mass sample

Table 1

Particle-size distribution of the fibrous-mass sample

№	Fractions (sieve aperture size)	Individual sieve residues		Notes
		Mass of fractions, g	Fraction content, %	
1	+20	100,0	3,80	The sample is dominated by cotton fibers
2	+10	30,0	1,14	The sample is dominated by cotton fibers
3	+5	20,0	0,76	The sample is dominated by cotton fibers
4	+2,5	115,0	4,37	The sample is dominated by lint fragments
5	+1,25	20,0	0,76	The sample is dominated by cotton fibers
6	+0,63	1360,0	51,72	The sample consists mainly of soil dust with lint inclusions
7	-0,63	985,0	37,45	Soil dust predominates in the sample
	Всего:	2630,0	100,0	

In the overall sample of the organomineral additive selected for testing, the mineral fraction accounted for 82.56%, while the organic fraction accounted for 17.44%. According to the particle-size distribution, the predominant fraction was the 0.63–1.25 mm fraction, which constituted 51.72% of the sample. The fraction smaller than 0.63 mm accounted for 37.45%, whereas the fraction larger than 1.25 mm constituted 10.83%. The organic component predominated in fractions larger than 1.25 mm, while the mineral component was mainly concentrated in fractions smaller than 1.25 mm.

The mineral fraction of the additive, corresponding to particles smaller than 0.63 mm, was examined by X-ray phase analysis. The X-ray diffraction pattern of the sample (Fig. 1) showed diffraction reflections characteristic of the following minerals: quartz at interplanar spacings of 0.424, 0.334, 0.245, 0.228, 0.212, 0.198, 0.181, and 0.154 nm; calcite at 0.303, 0.249, 0.228, 0.186, and 0.163 nm; and clay minerals at approximately 0.318, 0.216, and 0.200 nm.

The loss on ignition (LOI) of the organomineral additive at temperatures of 400 and 600 °C was determined by a chemical method in accordance with GOST 5382-91. The results are presented in Table 2.

Table 2

Mass fraction of loss on ignition in the organomineral additive

№	Fraction designation after sieving of the organomineral additive	Mass fraction of loss on ignition, %	
1	Fraction (−20 + 2.5) mm	71,14	3,09
2	Fraction (−2.5 + 1.25) mm	63,07	3,53
3	Fraction (−1.25 + 0.63) mm	22,88	3,26
4	Fraction smaller than 0.63 mm	14,64	3,52

The loss-on-ignition data presented in Table 2 confirm the previous conclusion that the organic component of the fibrous mass is concentrated predominantly in fractions larger than 1.25 mm. In contrast, fractions smaller than 1.25 mm are enriched in the mineral component.

Thus, the results of the preliminary investigations and tests demonstrated that the raw materials—the gypsum binder and the organomineral additive—are suitable for further studies aimed at evaluating the feasibility of using the fibrous mass as an organomineral filler in the manufacture of gypsum concrete products.

Tests to determine the physical and mechanical properties of the gypsum mortar containing 0.5–20% organomineral additive were conducted in accordance with the requirements of GOST 23789-79.

To optimize the material composition of the gypsum mortar containing the organomineral additive, mixtures were prepared using the gypsum binder and a composite sample of the organomineral additive. The compositions of the dry gypsum mixtures are presented in Table 3. Before use, the fibrous component of the organomineral additive was mechanically cut into pieces 5–7 mm in length.

After thorough dry homogenization of the components, the gypsum mixtures were mixed with water to obtain a workable consistency, with a water-to-gypsum ratio (W/G) of 0.43–0.46. Two batches of prismatic specimens measuring 4 × 4 × 16 cm were then moulded from each mixture. After 2 h of curing under ambient air conditions, the first batch of specimens was tested for flexural and compressive strength in accordance with GOST 125-79. The second batch of specimens was kept in a drying oven at 50–60 °C for 7 days. At the end of the drying period, the specimens were tested for flexural and compressive strength in accordance with GOST 125-79. The results of the physical and mechanical tests are presented in Table 3.

Table 3

Mix composition and strength characteristics of gypsum mortars containing the organomineral additive

№	Gypsum mortar designation	Mix composition of the gypsum mortar, %		Strength after curing for, kgf/cm²			
		Gypsum binder	Organomineral additive	2 hours		7 days	
				Flexure	Compression	Flexure	Compression
1	Gypsum mortar No. 1.	100	-	38,6	72,0	70,1	200
2	Gypsum mortar No. 2	99,5	0,5	25,4	58,0	48,8	89,5
3	Gypsum mortar No. 3	98,0	2,0	23,9	43,9	43,3	84,3
4	Gypsum mortar No. 4	95,0	5,0	22,1	38,0	40,0	81,2
5	Gypsum mortar No. 5	90,0	10,0	18,2	36,2	35,2	76,0
6	Gypsum mortar No 6	80,0	20,0	14,0	34,1	27,1	64,1

Analysis of the data presented in Table 3 showed that the incorporation of 0.5–20% organom. At the same time, the organomineral additive was found to have a positive effect on the development of the compressive and flexural strength of the gypsum mixtures. This indicates the feasibility of incorporating the organomineral additive into gypsum mixtures to improve the technological properties of gypsum-based products and reduce their production cost. The incorporation of up to 10% organomineral additive into gypsum concrete products is considered optimal. Gypsum board products are sheet finishing materials manufactured from building gypsum either as boards faced with cardboard on both sides or as boards consisting of a hardened gypsum matrix in which plant fibres are uniformly distributed, forming a reinforcing network.

В соответствии с ГОСТ 6266-97 «Листы гипсокартонные. Технические условия» листы в зависимости от свойств и области применения подразделяют на следующие виды: обычные (ГЛК); влагостойкие (ГКЛВ); с повышенной сопротивляемостью взаимодействию открытого пламени (ГКЛО); влагостойкие с повышенной сопротивляемостью воздействию открытого пламени (ГКЛВО).

Based on their appearance, gypsum plasterboards are classified into the following groups:

Group A — damage to corners and longitudinal edges is not permitted;

Group B — minor damage to corners and longitudinal edges is permitted.

Tests on the use of the organomineral additive in gypsum plasterboard products were conducted using standard GKL-type boards of Group A.

The main characteristics of gypsum plasterboards include the mass per unit area (surface density), which for GKL-type boards shall not exceed 1.00 × S kg/m², where S is the nominal board thickness in millimetres. The bond strength between the gypsum core and the cardboard shall be no lower than the interlayer bond strength of the cardboard itself. For 8 mm thick boards tested for flexural strength at a constant span of l = 350 mm, the breaking load shall be at least 17.4 kgf in the longitudinal direction and 6.8 kgf in the transverse direction.

The laboratory procedure used to prepare gypsum plasterboard specimens was designed to reproduce industrial production conditions as closely as possible and comprised the following operations: preparation of the moulding mixture by thoroughly homogenising the gypsum binder with the ground organomineral additive; mixing the moulding mixture with water; and subsequent forming of boards measuring 8 mm in thickness, 450 mm in length, and 150 mm in width between two cardboard facings coated with liquid glass.

After forming under slight compression, the specimens were cured in air at a temperature of 35–40°C for 24 hours. They were then dried at 50–60°C to a moisture content not exceeding 2% and tested for flexural strength in accordance with GOST 6266-97.

The report on the laboratory and technological tests and the test report on the physical and mechanical properties of gypsum plasterboards manufactured using the organomineral filler additive are presented in the Appendix..

Physical and mechanical tests established that the breaking load under flexural testing of 8 mm thick gypsum plasterboard specimens was 18.6 kgf, which meets the requirements of GOST 6266-97.

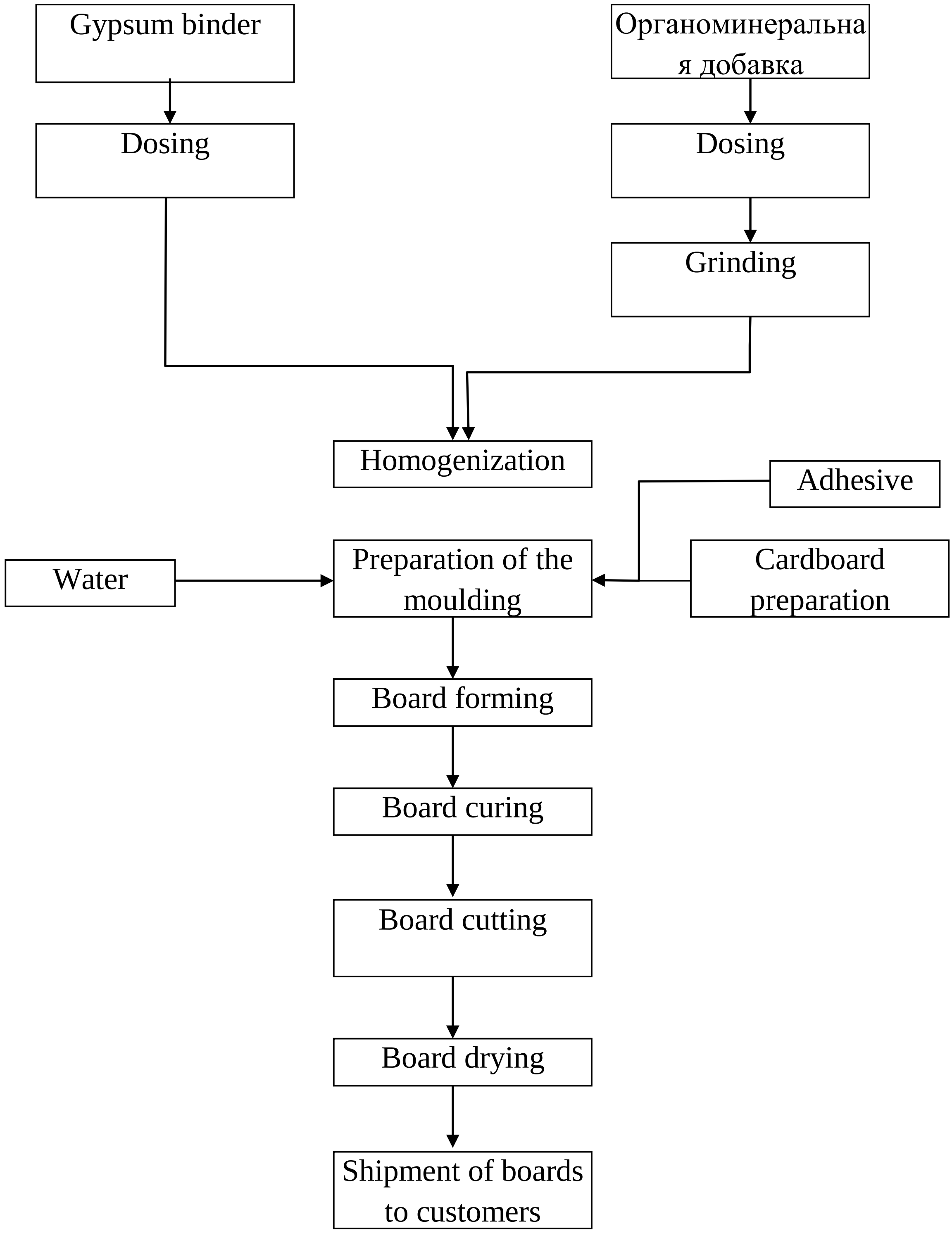

Figure. Process flow diagram for the production of gypsum plasterboards using an organomineral filler additive

The process flow diagram for the production of gypsum plasterboards using an organomineral additive, presented in Figure 3, was developed on the basis of the existing gypsum plasterboard manufacturing process and with due consideration of the results of the studies and tests conducted within the framework of the present project.

The gypsum plasterboard production process comprises the following operations: separate dosing of the gypsum binder and the organomineral additive in the specified mass ratio; grinding of the organomineral additive; homogenisation of the dry moulding mixture in a mixer; preparation of the moulding mixture by adding water until a workable consistency is achieved; and preparation of the upper and lower cardboard facing layers. The cardboard rolls are installed at two levels. The cardboard webs are unwound horizontally from the rolls, passed through guiding and braking devices, and fed onto the forming table. Before entering the forming section, the edges of the lower cardboard web are slightly trimmed to ensure proper folding during board formation. The edges of the upper cardboard web are first lightly ground, after which an adhesive composition is applied to them. The gypsum plasterboard web is then formed to the required thickness by distributing the moist moulding mixture over the lower cardboard layer, simultaneously covering it with the upper cardboard layer, and compacting the resulting web. The formed gypsum plasterboard web is cured on a conveyor and subsequently cut into boards of the specified dimensions. The boards are then dried in a tunnel dryer to a moisture content not exceeding 2% by mass, stored after drying, and finally dispatched to the customer as finished products.

Thus, the fibrous material captured during the treatment of air emissions from cotton-ginning plants is an organomineral mixture consisting of cotton fibres, lint, and soil dust. The organic fraction accounts for 10–20%, while the mineral fraction varies within the range of 80–90%. The material composition of the fibrous mass is favourable for its use in the production of construction materials. Physical and mechanical tests established the feasibility of incorporating up to 10% by mass of the organomineral additive into gypsum plasterboard compositions in order to improve their technological properties and reduce production costs. Laboratory-scale technological tests demonstrated that the fibrous mass, in an amount of up to 10%, can be used as an organomineral filler additive in the production of Type A gypsum plasterboards (GKL) in accordance with GOST 6266-97. A process flow diagram for the production of gypsum plasterboards using the fibrous mass as an organomineral filler additive was developed.

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