European Journal of Molecular & Clinical Medicine
ISSN 2515-8260 Volume 7, Issue 2, 2020

ASSESSMENT OF THE POTENTIAL OF COMPOSITE GYPSUM BINDER BRICKS AS AN ALTERNATIVE TO TRADITIONAL WALL MATERIALS IN UZBEKISTAN

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Abstract: The article discusses the possibility of producing bricks from a composite gypsum binder of increased water resistance from local raw materials and man-made waste. Experimental data demonstrate the dependence of the characteristics of the binder on the ratio of its components. The authors provide a comparative analysis of energy efficiency and other features of bricks made of the composite material and other wall materials.

Keywords: gypsum, brick, energy efficiency, composite gypsum binders

Introduction A modern society is now characterized by certain reinterpretation of the quality of life, and the priorities increasingly include values of sustainable development and healthy environment. Consequently, one of the main problems requiring urgent solutions in the name of a healthy ecosystem is a significant reduction in energy consumption.

The continuous provision of the world energy is forecasted to require about 2 trillion USD annual investments by 2035, while by 2030 the energy intensity of the world's GDP is expected to fall by 31%. Therefore, the energy efficiency has become a major trend in the world economy today, including all aspects of technological development, modernization and diversification of the economy. The policies of energy efficiency in developed countries had already boosted the competitiveness of the economy and production, the development of science, innovations, and the adoption of new technologies.

The building materials industry is one of the largest energy consumers, but the fuel efficiency in the industry does not exceed 40%. The construction industry has a very diverse pattern of energy consumption due to the variety of manufactured products and materials. Energy costs for the production of building materials and structures in Uzbekistan are more than 1.5 times higher than those of foreign countries, furthermore the end products are inferior to foreign ones in terms of energy efficiency.

The analysis showed that compared to the construction of facilities, the production of building materials is the largerst energy consumer, whilst the most energy-intensive is the production of cement, plate glass, precast concrete structures and products, wall materials, including thus the ceramic bricks [1].

Ceramic bricks are the ancient and first man-made artificial materials known to humanity, created more than 20 thousand years ago. The alumino silicate raw material used for the production of ceramic bricks, as well as their high firing temperature determine the chemical, thermal and biological stability of bricks, which, in turn, defines the wide range of their application: from the erection of exterior walls up to industrial furnaces [2].

Besides having the obvious advantages, like resistance to various external influences, high hardness, the ceramic materials still have certain significant disadvantages. Among these disadvantages is the need for high consumption of thermal energy during high-temperature firing, and consumption of mechanical energy during grinding minerals with strong crystalline bonds and post- firing mechanical processing of fired products. Decomposition is also important since that the broken ceramics hardly decompose due to their durability features.

From this perspective the basic energy-saving approaches for production of wall materials are as follows:

- shape modification in order to reduce their weight and increase functionality;
- use of new types of raw materials and their preparation in order to reduce energy costs.

Like many researchers, the authors are developing alternatives to ceramic bricks that can replace it as a wall material.

Ceramic bricks can be replaced by materials made of different materials and shapes, yet the few alternatives available in the market are the silicate, fireclay, clinker and hyperpressed of traditional brick-size. The authors consider the bricks made of composite gypsum binder as one promising material with competitive features.

Gypsum by itself is hardly suitable as a raw material for wall bricks due to the poor water resistance properties, which is a big disadvantage resulting in high creep moisture, low strength, low frost resistance, etc. However, the energy efficiency and eco-friendliness are the advantages that should be taken into account, the more so considering a reduced use of energy resources and decreased production of carbon dioxide at gypsum production. So when analyzing the use of gypsum through this kind of "green" prism, this material is the best one for construction.

Thenumerous studies on improvement of water resistance properties of the gypsum suggest the following methods:

➢increasing the density of the product by tamping and pressing of low-plastic mixtures;

➢increasing the water resistance of gypsum products by means of the surface and bulk hydrophobic treatment, by impregnating with substances that prevent moisture penetration;

➢use of chemical additives, e.g. plasticizers that allow modifying various properties of gypsum;

➢formation of insoluble compounds that protect calcium sulfate dehydrate via a combination of gypsum binder with hydraulic components (lime, portland cement, active mineral additives) [3].

The important work was made by Volzhensky A.V., Ferronsky A.V. and Rebinder P.A, who invented the gypsum-cement-pozzolan binders based on construction gypsum and solved the problem of low water resistance and forced to reconsider the scope of the gypsum binder use. The second group of scientists from the Moscow Civil Engineering Institute named after Kuibyshev, namely Korovyakov V.F., Stambulko V.I., Volzhenskiy A.V., Ferronskaya A.V. who could improve the first received composite gypsum binders by increasing their water resistance [3].

The authors analyze the options of local production of bricks from composite gypsum binders (CGB bricks) and assess the market potential of the new wall material.

Uzbekistan has relatively rich gypsum deposits, the production of all types of gypsum binders, like Portland cement, and production of all types of gypsum binders has been established for a long time (9681.1 thousand tons of Portland cement produced in 2019). Two basic components of CGB bricks are easily available, yet, the selection of the third component - active micro silica, remains challenging since not every silica raw materials are suitable [4].

To address this issue several silica-containing waste as ash and slag wastes from thermal power plants, tailings, etc. were tested. The magnetic separation waste from glassware production (JSC "Quartz") was finally selected. The analysis showed that the waste contains quite a large amount of X-ray amorphous substances, which determine their hydraulic activity when interacting with $Ca(OH)_2$, along with formation of calcium hydrosilicates (Table. 1). The pozzolanic activity of the mill ground waste aged 30 days made up 12 5.1 mg g^{-1} (Table. 2).

The plant (JSC "Quartz) has sufficient reserves of magnetic separation waste and therefore a rich raw material base to be used for the industrial production of CGB-bricks, however this type of waste has high iron content, which is a main disadvantage.

Table 1. Composition of magnetic separation waste

Substance	SiO_2	$Al_2 O_3$	Fe_3O_4	CaO	MgO	SO_3	CO_2
Content,%	68-77	0.7 - 2.27	10,2-17.7	1,67	1,83-2,26	0,12 – 0,15	3,63

This type of waste represents a man-made (technogenic) fine sand of dark gray color, consisting of sharp-edged quartz particles (about 60%), metal oxides, carbonates, hematite and aggregates. The size modulus is significantly below 1, while the content of particles of less than 0.074 mm is about 80 - 85%.

Table 2. Activity of the mill ground waste from magnetic separation

CaO in mg absorbed by 1 g of the mineral supplement in time		**Sludge volume, cm^3**
2nd day	4,9	5,61
30 days	126,7	

For use as a siliceous additive, the waste was milled in a ball mill until the powder reached a specific surface of 500 m^2 kg^{-1}, as it was found that for a composite binder it should not exceed 600 m^2 kg^{-1}. To confirm the activity of the powder it was mixed with cement in different proportions, and the strength characteristics of the mixture were checked after 28 days (Table 3).

Table 3. Indicators of compressive strength of a mixture of silica-portland cement aged 28 days

No.	Powder,%	Portland cement,%	Strength, MPa
1	50	50	22.1
2	60	40	21.4
3	40	60	23.6

The findings confirm the reactivity of the finely dispersed powders, which is consistent with the activity indicators (Table 2).

Following the testing of micro silica additive, it was required to determine the specific proportions of the components. For this, after grinding the waste, it was crushed together with cement and chalk-containing additive (1% of the total mass), while the optimal time for preparation and re-grinding of the modifier was determined as 5 minutes. The chalk-containing additive, a waste from soda production, was added to ensure the stability of the composite binder, as well as to exclude the formation of ettringite over time and to maintain the required concentration of $Ca(OH)_2$ during hardening (Table 4)[7-8].

Table 4. Composition of the soda production waste by JSC "Fargonaazot"

Substance	SiO_2	$CaCO_3$	$MgCO_3$
Content,%	2-4,2	85-88,7	2,4-2,5

The selection of the specific proportions of CGB components was done empirically considering that the concentration of CaO in the aqueous suspension of a mixture of semi-aqueous gypsum, portland cement and micro silica powder did not exceed 1,1 g L^{-1} on the fifth day, and no more than 0,85 g L^{-1} on the seventh day. The resulting ratio of the binder components was used as the basis for calculating the composition of the composite binder as follows: 69gypsum binder / 15 portland cement / 15 finely ground magnetic separation waste / 1 chalk containing waste.

To increase the efficiency of the binder, the modifier was mixed with a gypsum binder within 3 min. Then water was mixed with the required volume of binder comprising rational number gypsum of grades G-5 and G-16, and mineral modifiers (MM). Samples were press tested on day 28. The characteristics of the CGB brick mixtures depending on the composition are presented in Table 5.

Table 5. Properties of CGB brick depending on the composition

No.	CGB brick composition,%			W /Bind	Spread, m	Strength for 28 days, MPa		Cr	Frost-resistance, cycles
	G-5, β	G-16, α	MM			Bending	Compression		
1	61	8	31	0,50	0,150	5,4	18,2	0,76	45
2	56	13	31	0,50	0,150	6,2	18,8	0,76	45
3	51	18	31	0,50	0,145	6,4	19,4	0,82	45
4	46	23	31	0,50	0,145	9,2	21,6	0,87	50
5	35	35	31	0,50	0,180	8,2	17,8	0,82	45
6	61	8	31	0,45	0,120	8,6	19,6	0,84	50
7	56	13	31	0,45	0,110	9,2	20,0	0,84	50
8	51	18	31	0,45	0,125	9,8	21,8	0,86	55
9	46	23	31	0,45	0,120	10,6	25,2	0,88	60
10	35	35	31	0,45	0,160	8,8	18,4	0,84	50

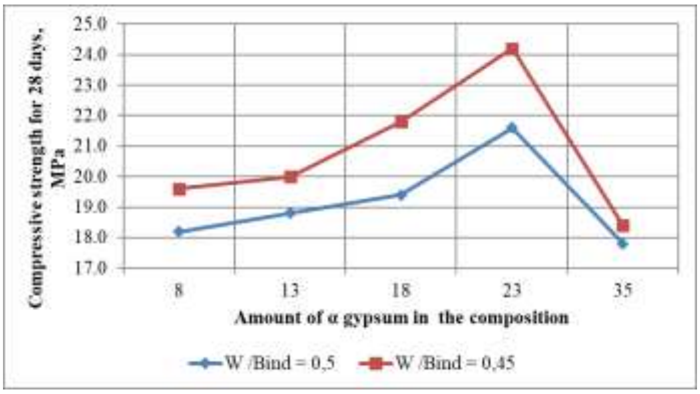

Figure 1. Dependency of the strength of CGB brick on the amount of alpha gypsum

As shown in the table, the physical and mechanical indicators of CGB brick made from local raw materials meet the requirements of a binder used for the production of building materials, products and structures, meaning the water resistance coefficient of 0.88, and the strength of 25.2 MPa at age of 28 days.

The production of CGB bricks has a number of advantages over ceramic bricks and similar wall materials based on other binders, including portland cement, as follows:

- low consumption of equivalent fuel and energy due to the production without heat treatment;
- increasing the turnover of molding equipment;
- no artificial drying is required;
- cost reduction due to the use of local raw materials and man-made waste along with a solution to environmental problems.

Table 6. Average data on the properties of various types of bricks

Brick type	Brand	Average density, kg·m^{-3}	Thermal conductivity, W/(m*K)	Water absorption,%	Frost resistance, cycles
Silicate	M75-M300	1000-2200	0,5-1,3	12	15-50
Ceramic corpulent	M200-M300	2100	0,72	8	50-75
Ceramic hollow	M125-M150	1100-1150	0,2 0 26	6-8	35
Hyperpressed	M50-M300	2200	0,9-1	6-7	25-200
Clinker	M400-M1000	1900-2100	1,16	6	50-100
Fireclay	M75-M500	1700-1900	0,6	15-30	15-50
Solid concrete on CGB	M50-M75	1400-1700	0,52-0,7	4-6	50-75

As the Table 6 demonstrates, the wall materials based on CGB bricks are the best solution for the construction of both residential buildings and various agricultural premises.

If we take as 100% the energy consumption for the production of a single ceramic brick, which is now a traditional wall material, then the comparable electricity costs for the production of CGB brick-based wall stones of the same volume will be 0.7% (Table 7).

Table 7. Energy consumption at production of bricks from different materials

Type of wall material	Power consumption , kWhr	Energy consumption ,%
Ceramic brick	96,31	100
Silicate brick	15,58	16,2
Wall blocks made of aerated concrete	14,65	15,2
Vibro-pressed concrete wall stones	4,04	4,2
Concrete wall stones on CGB bricks	0,67	0,7

According to data shown in Table 6 and Table 7 the use of a CGB brick-based concrete as a wall material, which has a slightly lower strength as compared to analogs, is more effective compared to other bricks, since the production does not require post forming heat treatment, leading to decreased labor costs and energy savings, which greatly affects the overall cost.

In Uzbekistan, as elsewhere in the world, the "green" construction is turning into fashion, which will require completely new demands to the quality of life and the organization of the environment. The latest presidential decrees have repeatedly emphasized the energy efficiency of manufactured products. Since last year, Uzbekistan has already begun a phased transition from the production of energy-intensive building materials to energy-efficient alternative types of products. It is now obvious that ceramic bricks will become a thing of the past and will be replaced with a more “friendly” analogue in the near future [5-6].

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