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Optimization of the Composition and Properties of Effective, Wide Format, Ceramic Stones

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Annotation: *Energy saving is currently considered by developed countries as the most important national environmental and economic problem. Measures that ensure energy conservation are more cost-effective than those from the creation of energy resources. The rational use of fuel, raw materials and other material resources is becoming a decisive factor in the successful development of ceramic production in the context of economic reforms and unfavorable environmental conditions in the developed countries of the world. In this regard, the problem of obtaining large-format ceramics in the production of wall materials is a particularly urgent and unresolved problem. This article presents the results of scientific research and laboratory testing of the introduction of screenings from the Angren coal basin in the production of porous large-format wall stones. Attempts have been made to modify the composition of the molding sand used for the production of wall stones. As a result, high rates of heat-insulating, multi-slit wall stones were obtained, which is one of the promising areas in the field of energy-efficient construction.*

Keywords: *bio-filler, breathable conglomerate, thermo physical modeling, bio-resources, fractions, coal preparation screenings, siltstone, mudstone, sandstone, large-format ceramics, wall stones, multifactorial experiment planning, regression equation.*

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1. Introduction

In recent years, screenings from the Angren mine have been actively studied as a raw material for porous ceramics. Interest in this coal residue as a raw material for the production of wide format building stones has increased significantly. In the world, the principle (concept) of using energy-saving and environmentally friendly technologies in the production of ceramic building materials is becoming increasingly important. The development of the construction industry involves the expansion of types of ceramic products for exterior walls and an increase in their production. One of the promising areas of development is the production of ceramic stones with a coefficient of 2.1NF.

Currently, the mining district of the Tashkent region (Angren coal mine) is being actively implemented in order to process coal dumps, which is economically feasible and relevant in the production of wall materials. In the process of sorting coal residues in dumps, a number of materials of various grain size and chemical and mineralogical composition are formed. In addition to coal tailings, the composition of which usually ranges from 10 to 20%, the main rocks that make up the tailings are siltstones, mudstones and sandstone minerals Fig. 1 [1].

The technology for the production of ceramic multi-slotted wall stone based on dumps of coal mining waste has its own characteristics, which are associated with some properties of the raw material. The production of a ceramic stone (block) with the required properties can be included in the composition of the raw clay mass. The main product must comply with the requirements of the standard [2]. Screenings of medium size are of the greatest interest as a raw material for the production of ceramic stone (blocks), which are materials with a particle size of 2 to 6 mm. They are not used for other purposes, their composition is the same and we can say that they are almost ready for production. Composition of the main sorted minerals: - feldspar, quartz, mica and hydromica are rocks. Feldspar is mainly represented by orthoclase and albite. They undergo strong secondary changes - pelleting and chlorination. Hydrolite (illite) is a typical clay mineral with the same 2:1 structural packing as montmorillonite, but in contrast to it, the tetrahedral layer always contains aluminum ions isomorphically replacing silicon ions, and the resulting packing charge is covered with potassium ions. There are also secondary iron minerals in the form of oxides and hydroxyls. For the production of ceramic) stone (blocks) samples, technogenic coal dumps are used with the addition of 10-30% clay. The ratio of these components may vary depending on the composition of the initial mine waste [3-6].

2. Materials and methods

Selection of the amount of materials that make up the molding sand and research methods

The following materials were accepted as components included in the initial composition:

- techno genic coal screening - dumps of resorted particles;
- Clay quarry JV "CERAMIC BRICKS" LLC located in the Zhambay district of the Samarkand region.

Optimization of the composition of the ceramic mass using non-traditional raw materials was carried out by the method of mathematical planning of the experiment. The experiment was carried out using the PFE-23 full-factor experiment. The following factors are accepted as variable factors: X1 – ceramic shard firing temperature, °C; X2 – grain size (fraction) of particles of coal screening;

X3 - the amount of addition of clay soil,%. The factors used in the experiment and their variation are shown in Table 1.

Table 1 Variable factors and limits of their change

Indicators	Notation	Variable factors		
		X_1, °C	X_2, мм	X_3, %
Minimum value	X_{min}	900	0,16	10
Maximum value	X_{max}	1100	0,63	30
Variation intervals	ΔX	100	0,235	10
Basic meaning	X_0	1000	0,315	20

Table 2 Matrix of the plan of the full factorial experiment PFE-23

№	Coded values for variable factors		
	X1	X2	X3
1	-1	-1	-1
2	1	-1	-1
3	-1	1	-1
4	1	1	-1
5	-1	-1	1
6	1	-1	1
7	-1	1	1
8	1	1	1

Indicators obtained as a result of experiments:

- Y1 – compressive strength, Rcompressive strength, kgf/cm2 (MPa);
- Y2 – ultimate strength in bending, Rbend, kgf/cm2 (MPa);
- Y3 - water absorption coefficient of the material, W, %.

The preparation of plastic clay mass for experiments was carried out as follows: coal screenings were mixed in an oven at T = 105 ± 5°C, then crushed to the required fraction in a jaw crusher. Then, 10, 20 and 30% clay from the quarry was added to the sorted coal screenings. Water was sprayed in a sprayer to moisten the mixture. The mixture was then thoroughly mixed until a clay mass with moderate formability was formed. Samples from the clay mass were molded under high pressure.

After samples were pressed from the molding mass and the moisture in it was evenly distributed, it was allowed to rest for a day. Later, cube-shaped samples were made, with dimensions of 50 x 50 x 50 mm and beam samples of 135 x 30 x 15 mm. The samples were kept under normal conditions for a day and then dried in an oven for 24 hours at T = 105°C. Then the samples were baked at a given temperature.

After firing, the experimental samples were tested.

The results of experiments and test values are given in table. 3.

Table 3 Indicators obtained as a result of experiments

№	R_f, kgf/cm^2 (MPa)	R_c, kgf/cm^2 (MPa)	W, %
1	6.40	63,63	16.76
2	10.76	43,20	14.89
3	8,97	26,97	4.41
4	6,97	78,23	16.30
5	11,57	66,73	14.14
6	5,40	155,83	0.95
7	12,50	39,67	18.66
8	7,57	57,57	14.87
9	14,63	128,8	0.34

3. Analysis of experiments and results

Mathematical processing was carried out in programs such as Excel and MathCad to optimize the results of factorial experiments. A semiquadratic polynomial equation was chosen as a mathematical model:

Y = B0 + B1X1 + B2X2 + B3X3 + B12X1X2 + B13X1X3 + B23X2X3 (1)

Statistical analysis of the regression equations obtained for each response was evaluated according to three criteria: the homogeneity of the variances, the significance of the coefficients, and the adequacy of the Fisher criterion [9-10]. As a result of the experiment and regression analysis, the values of the coefficients are presented in Table 4.

Table 4 Regression Equation Coefficients

Notation	Values Meaning and name of coefficients						
	B_o	B_1	B_2	B_3	B_{12}	B_{23}	B_{123}
Y_1	8,21	1,94	-	-	-0,48	-0,9	-0,99
Y_2	67,10	16,6	-16,5	12,85	10,15	-14,8	-18,5
Y_3	10.14	-0,22	-7.36	0.78	0.6	-	1.34

As a result of a series of experiments, molding masses of ceramic composition products were obtained, which are distinguished by a wide range of physical and mechanical properties. The range of variation of the experimental values of the studied factors is presented in Table 5.

Table 5 the range of changes in the main indicators of the quality of the ceramic mass

Bending strength interval, kgf/cm2 (MPa)	Compressive strength interval, kgf/cm2 (MPa)	Material water absorption coefficient, %
5,40-12,5	**26,97-155.83**	**0,34-18,66**

In practice, for the purpose of operational management of technological processes, various graphical constructions are usually used, which allow you to quickly set the values of various factors, taking into account the specifics of production, for any Y=const. In this case, Y=const corresponds to an infinite number of fluctuations Xi, and the factors are already independent, each of them becomes a function of the others. The most convenient form of graphical representation of this established relationship is an image on the coordinate plane, in which one of the factors stabilizes at a constant level, and the other two change within a given range of changes (Fig. 1-2) . The use of such graphs helps to easily determine the conditions necessary to obtain products of one quality or another in terms of strength, density, etc.

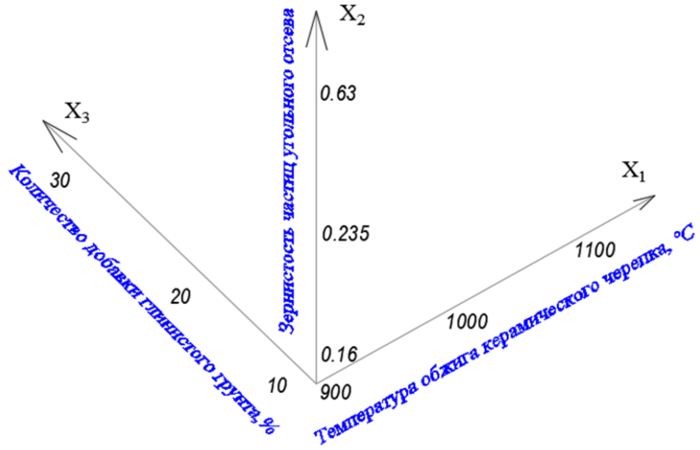
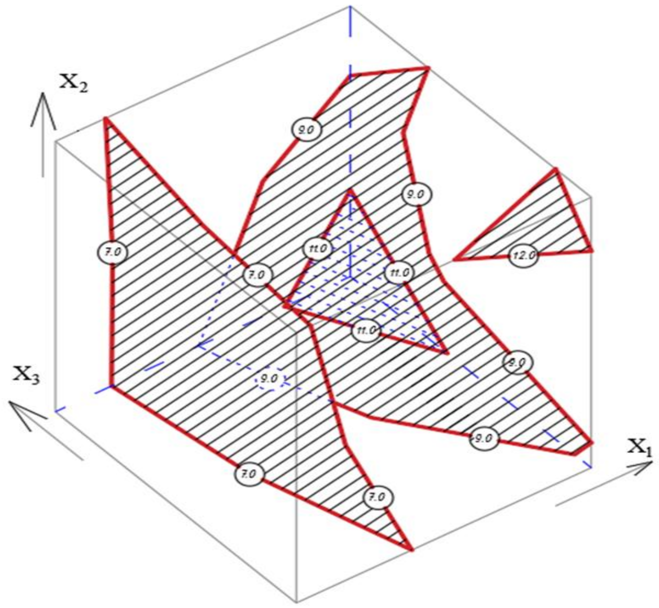


Fig.1. Diagram of the dependence of the flexural strength of a ceramic stone (block) depending on the firing temperature X1, the size of the coal screening fraction X2, and the addition of clay mass X3



Y=8, 21+1, 94X1-0, 48X1X2-0, 9X2X3-0,99X1X2X3

4. Discussions

With the help of such regression equations, it seems possible to determine the entire range of values of output parameters in the studied area of the factor space, and then a graphical representation of the nature of the change in the studied characteristics [9-10].

A general analysis of the influence of the firing temperature of ceramics, the fractional composition of coal residues and clay additives on the compression and bending forces of the fired stone block and the water absorption index of fired laboratory samples shows that the obtained dependences are linear. (Fig. 1-2).

Bending strength in sintered ceramic elements is one of the most important characteristics that determine the brand of products and determine their quality. The interpretation of the strength of the product, depending on the firing temperature of the clay shard and the consumption of clay with a constant size, showed that the fractional composition (screening) of technogenic raw materials and a decrease in grain content from 0.63 to 0.16 mm have the greatest influence on this indicator, and in the fired shard strength of samples increases significantly. This is due to an increase in the level of contact between granular particles and an increase in the level of ceramic sintering.

According to the results of experimental experiments, an increase in the strength of the fired stone (block) under the action of finite bending forces is observed. This is explained by the fact that screenings represented by siltstone in coal mining tailings consist of rapidly soluble minerals: mica, hydromica, feldspars, iron hydroaluminosilicates and other minerals. This contributes to the active process of firing ceramics with the optimal amount of fine fractions, represented by clay minerals.

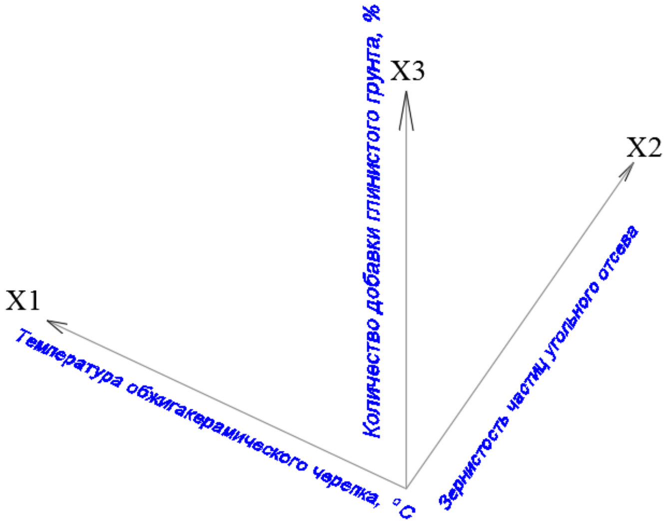
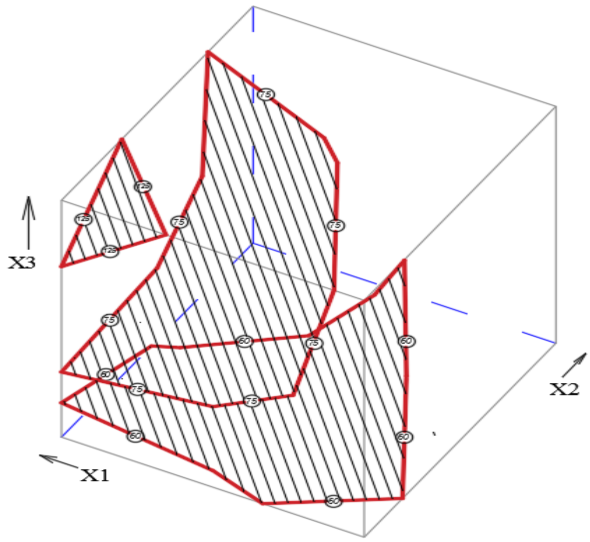


Fig.2. Diagram of the dependence of the compressive strength of a ceramic stone (block) depending on the firing temperature X1, the size of the coal screening fraction X2, and the addition of clay mass X3



Y=67,10+16,6X1-16,5X2+12,85X3+10,15X1X3-14,8X2X3-18,5X1X2X3

Changing the firing temperature of the clay also affects the tensile strength, the bending of the fired stone. From the presented data (Table 3) it can be seen that with an increase in the firing temperature, the final bending strength also increases, which is natural for ceramic firing technology. The most significant factor affecting the level of consistency is observed with an increase in the sintering temperature and an increase in the degree of grinding of the coal screening (screening).

Processing of the experimental composition of waste heaps from coal mining dumps shows that the tested samples exceed the compressive strength up to 1.55 MPa, while the required for the M125 ceramic block (up to 1.25 MPa) according to O'zDSt3255-2017, which is 24% higher than the standard. Given that stones (blocks) contain a large number of holes, their strength can be 10 ... 12% strength. Thus, it can be concluded that ceramic products based on waste heaps have high bending strength. The same relationships are observed for the ultimate compressive strength. The resistance of the studied factors to the influence of compressive forces can be classified as follows: the composition of the fraction (screening out) of coal residues X2 > the firing temperature of ceramics X1 > the amount of clay in the composition X3. As can be seen from the bending strength Rben, the strength Rco of fired ceramics increases with the melting of the grain size (fraction) of the raw material and an increase in temperature from 900 to 1100 °C. This is due to an increase in the level of contact between raw soil grains and an increase in the level of ceramic sintering.

5. Conclusion

Based on the studied factors, the analysis of the effect of water absorption of fired clay shows that X2 has the main effect on the studied index of the fractional composition of the ceramic mass. In this case, the variable factors, the addition of clay X3 and the firing temperature of ceramics X1, are practically the main ones. Thus, after firing, the ceramic shard has the desired porous structure, which in turn affects the water absorption of the material. The results obtained on the selection of the composition of ceramic masses using technogenic raw materials - coal mining screenings show that the water absorption of ceramic samples directly depends on the firing temperature. Ceramic samples demonstrate water absorption of more than 6% up to a temperature of 1000 °C and less than 6% when the temperature rises to 1100 °C. All this makes screening waste heap destruction a very promising raw material for highly efficient ceramic blocks, which are the most promising wall products for modern construction.

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