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PAPERS IN ENGLISH

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MATHEMATICAL MODELING OF THE PROPERTIES OF EFFECTIVE CERAMIC BRICK WITH BURN-OUT ADDITIVES FROM AGRICULTURAL WASTES

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МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ СВОЙСТВ ЭФФЕКТИВНОГО КЕРАМИЧЕСКОГО КИРПИЧА С ВЫГОРАЮЩЕЙ ДОБАВКОЙ ИЗ СЕЛЬСКОХОЗЯЙСТВЕННЫХ ОТХОДОВ

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Abstract. Results of scientific research on determination of optimum prescription and technological parameters of effective ceramic brick with burn-out additives, obtained by the method of mathematical planning of experiments are given in the article.

Keywords: porous ceramics, brick, burn-out additives, mathematical planning of experiments, a dosage of technological additive, forming moisture content, pressure in an extruder.

At present, with increasing regulatory requirements for thermal resistance of external enclosing structures of residential buildings in the Republic of Uzbekistan, a special attention is paid to the issue of increasing the thermal insulation characteristics of the traditional and most affordable local building material - ceramic bricks. One way to increase the thermal insulation properties of ceramic bricks is an addition of organic burn-out additives to the clay mass. This method, along with a significant increase in the porosity of ceramic crock, also allows the utilization of massive industrial and agricultural waste.

Tashkent Institute of Architecture and Construction for several years has been conducting theoretical and experimental research to substantiate the possibility of obtaining a highly effective ceramic brick with technological additives based on cotton stems – “guza-paya”.

This article presents the results of mathematical modeling of the properties of effective ceramic bricks with burn-out additives from agricultural waste. To model the properties of effective ceramic bricks, the method of mathematical planning of experiments is used [1].

In the process of modeling, the following prescription and technological parameters are chosen as variable factors:

x_1 - dosage of technological additive in % of clay mass;

x_2 - forming moisture content, %;

x_3 - pressure in the extruder, MPa.

Intervals and levels of factor variation are presented in Table 1.

The levels of remaining factors are stabilized for the whole experiment. The firing of samples is carried out at temperature 1000^0C.

B3 type of experiment plan is chosen as a planning matrix.

To implement the planning matrix, samples have been produced and tested in accordance with the current governmental standards. The main characteristics of the plan and the experiment plan in coded and natural values of variables are presented in Tables 1 and 2.

Table 1.

Main Characteristics of the Plan

Code	Value of code	Values of factors		
		X_1	X_2	X_3
		dosage of technological additive, %	forming moisture content, %	pressure in the extruder, MPa
Basic level	0	10	20	1,2
Variation interval		5	4	0,2
Upper level	+1	15	24	1,4
Lower level	-1	5	16	1,0

Table 2.

Experiment plan in coded and natural values of variable factors

No of experiments	Experiment plan			Natural values of experiment		
	X_1	X_2	X_3	X_1	X_2	X_3
1	+1	+1	+1	15	24	1,4
2	+1	+1	-1	15	24	1,0
3	+1	-1	+1	15	16	1,4
4	-1	+1	+1	5	24	1,4
5	-1	-1	-1	5	16	1,0
6	-1	+1	+1	5	24	1,4
7	-1	-1	-1	5	16	1,0
8	+1	-1	-1	15	16	1,0
9	+1	0	0	15	20	1,2
10	-1	0	0	5	20	1,2
11	0	+1	0	10	24	1,2
12	0	-1	0	10	16	1,2
13	0	0	+1	10	20	1,4
14	0	0	-1	10	20	1,0
15	0	0	0	10	20	1,2

During the tests at a temperature of 1000^{0}C, the structural strength of freshly formed samples, their average density and compressive strength were established.

Average values of experimental data for each point of the plan are given in Table. 3.

As a result of experiment plan implementation, compositions of ceramic masses which differ in a wide range of physical-mechanical properties were obtained by the method of plastic forming. The range of changes in experimental values of indicators is given in Table 4.

Table 3.

Results of experiment plan implementation

No of experiments	Levels of variation factors			Average values of experimental results		
	X_1	X_2	X_3	$R_{стр}$, MPa	$R_{сж}$, MPa	$\rho_{ср}$, kg/m^3
1	+1	+1	+1	2,07	10,45	1080
2	+1	+1	-1	1,48	10,35	1045
3	+1	-1	+1	1,70	6,80	1096
4	-1	+1	+1	1,51	8,15	1042
5	-1	-1	-1	0,67	4,40	980
6	-1	+1	+1	1,01	5,55	1020
7	-1	-1	-1	1,23	5,70	1005
8	+1	-1	-1	1,19	5,00	986
9	+1	0	0	1,85	9,25	1065
10	-1	0	0	1,36	5,15	1035
11	0	+1	0	1,71	8,65	1070
12	0	-1	0	0,93	5,55	1032

13	0	0	+1	1,86	7,92	1062
14	0	0	-1	1,25	5,27	1019
15	0	0	0	1,70	6,96	1052

Table 4.

Range of changes in main quality indicators

Structural Strength of Raw Material, MPa	Strength limit of brick under compression, MPa	Average density, kg/m³
0,67-2,07	5,00-10,45	986-1096

The results of experiment plan implementation (Table 5) were processed using the methods of mathematical statistics [2].

Table 5.

Calculated values of experimental results

No of experiments	Levels of variation factors			Design values of experimental results		
	X_1	X_2	X_3	$R_{стр}$, MPa	$R_{сж}$, MPa	$\rho_{ср}$, kg/m³
1	+1	+1	+1	1,89	10,46	1075,96
2	+1	+1	-1	1,31	10,58	1039,56
3	+1	-1	+1	1,49	7,32	1052,26
4	-1	+1	+1	1,37	7,74	1046,36
5	-1	-1	-1	0,43	4,04	968,26
6	-1	+1	+1	0,77	5,64	1022,66
7	-1	-1	-1	1,03	5,5	1009,96
8	+1	-1	-1	0,91	5,08	997,86
9	+1	0	0	1,65	8,95	1063,88
10	-1	0	0	1,15	5,57	1034,28
11	0	+1	0	1,4	9,05	1066,68
12	0	-1	0	0,9	5,25	1033,98
13	0	0	+1	1,63	7,75	1062,28
14	0	0	-1	1,17	5,51	1016,88
15	0	0	0	1,4	6,81	1056,19

After processing the results obtained, the following polynomial models, adequately describing the relationship between the properties studied and initial factors have been obtained:

- structural strength of raw materials, MPa:

$$R_{стр} = 1,60+0,25X_1+0,25X_2+0,23X_3-0,25X_2^2 - 0,05X_1X_2+0,06X_1X_3; \quad (1)$$

- strength of ceramic bricks under compression, MPa

$$R_{сж}=6,81+1,69X_1+1,9X_2+1,12X_3+0,45X_1^2+0,34X_2^2 -0,18X_3^2+1,01X_1X_2+ 0,16X_1X_3 +0,16X_2X_3; \quad (2)$$

- average density of ceramic bricks; kg/m³:

$$\rho_{ср}=1056,19+14,8X_1+16,35X_2+22,7X_3-7,11X_1^2-5,86X_2^2-16,61X_3^2-4,5X_2X_3; \quad (3)$$

Obtained mathematical models of density and strength under compression of ceramic crock after processing according to the "Optim" program allow to determine the optimum prescription and technological parameters for obtaining effective ceramic brick of required (in strength and density) brand; they are: - dosage of technological additive - 5.8% of clay mass; - forming moisture content - 20.1%; pressure in the extruder - 1.25 MPa.

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2. Voznesensky V.A. Statistical Methods of Experiment Planning in Technical and Economic Studies. - Moscow: Statistics, 1981. - Pp.152-250.