Optimal parameters of physical and mechanical properties of sawdust concrete

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Abstract. The purpose of the conducted experimental studies is to examine the effect of various influences on the object of study. These effects are called factors. Some of them vary while examining of the object and then they are called variable factors. Each factor takes one or more values in the experiment and then they are called factor levels. The set of values of this factor is called range of factor values – the smallest interval, where are all the values accepted by this factor in the experiment. According to GOST 19222-84, the dependence of the physical-mechanical characteristics of sawdust slag concrete (grade M10) on the specific gravity (share) of wet sawdust of coniferous species and ash-slag mixture in the composition was studied. Regression analysis was used to build a mathematical model of the process with quantitative factors, to verify its adequacy, and to assess the impact of each variable factor on the process. To obtain regression dependencies, a composite second-order B-plan was implemented.

1 Introduction

The purpose of the conducted experimental studies is to examine the effect of various influences on the object of study. These effects are called factors. Some of them vary while examining of the object and then they are called variable factors. Each factor takes one or more values in the experiment and then they are called factor levels. The set of values of this factor is called range of factor values – the smallest interval, where are all the values accepted by this factor in the experiment [1-9].

2 Materials and methods

A two-factor experiment was carried out in the laboratory of the Department of Reproduction and Processing of Forest Resources, Federal State Budgetary Educational Institution of Higher Education "Bratsk State University" in order to justify the specific share of wet sawdust in the composition of sawdust concrete, to determine the necessary number of observations and repetitions of the experiment. As a variable factor, the

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proportion of wet sawdust of coniferous species in the composition is assumed. The proportion varies from 17% to 37% in increments of 5% [10-18].

The qualitative indicators of the final product (heat-insulating sawdust concrete of grade M10) were taken as output values:

Y1 – average density, ρavg, kg/m3;

Y2 – humidity, W, %;

Y3 – compressive strength, σcf, MPa;

Y4 – sorption moisture, As, %.

Variable experiment factors:

X1 – percentage of wet sawdust of coniferous species in the composition, dsd, %;

X2 – percentage of ash-slag mixture from the volume of air-slaked lime in the composition, das, %.

3 Results

Based on these requirements, the range of variation of variable factors is assumed equal to 5%. Tab. 1 shows the variable factors in natural and code designation, their levels and range of variation, when conducting a two-factor experiment.

Table 1. Main factors and their levels of variation.

Name of the factor	Design a-tion	Lower level	Main level	Upper level	Range of variation
The proportion of wet sawdust of coniferous species in the composition, %	X_1	17	27	37	10
The proportion of ash-slag mixture from the volume of lime, %	X_2	0	12,5	25	12,5

The constant factors of the experiment have the following meanings:

- air temperature 23 ± 1 °C;
- air humidity 45 ± 5 %;
- species composition of sawdust – coniferous;
- moisture content of sawdust – 6.0 ± 0.1 %;
- fractional composition of sawdust – 0.5...5 mm;
- the size of the obtained samples – 100x100x100 mm;
- air-slaked lime consumption – 25.0 kg per 1 m3 of the mixture;
- sand consumption – 265.8 kg per 1 m3 of the mixture;
- water consumption – 300.0 l per 1 m3 of the mixture;
- water glass consumption – 8.0 kg per 1 m3 of the mixture.

According to GOST 19222-84, the dependence of the physical-mechanical characteristics of sawdust slag concrete (grade M10) on the specific gravity (share) of wet sawdust of coniferous species and ash-slag mixture in the composition was studied.

Regression analysis was used to build a mathematical model of the process with quantitative factors, to verify its adequacy, and to assess the impact of each variable factor on the process.

To obtain regression dependencies, a composite second-order B-plan was implemented.

The planning matrix of the experiment is presented in Tab. 2.

At the next stage, a multi-factorial experiment was conducted in order to obtain an adequate mathematical description of the technological production of sawdust slag concrete of the proposed composition.

Table 2. Planning matrix for two controllable factors.

Experiment number	x_1	X_1, d_{sd}, %	x_2	X_2, d_{as}, %	Y_1, ρ, kg/m^3	Y_2, *W*, %	Y_3, σ_{cf}, MPa	Y_4, A_s, %
1	2	3	4	5	6	7	8	9
1	-1	17	-1	0	Y_{11}	Y_{21}	Y_{31}	Y_{41}
2	+1	37	-1	0	Y_{12}	Y_{22}	Y_{32}	Y_{42}
3	-1	17	+1	25	Y_{13}	Y_{23}	Y_{33}	Y_{43}
4	+1	37	+1	25	Y_{14}	Y_{24}	Y_{34}	Y_{44}
5	-1	17	0	12,5	Y_{15}	Y_{25}	Y_{35}	Y_{45}
6	+1	37	0	12,5	Y_{16}	Y_{26}	Y_{36}	Y_{46}
7	0	27	-1	0	Y_{17}	Y_{27}	Y_{37}	Y_{47}
8	0	27	+1	25	Y_{18}	Y_{28}	Y_{38}	Y_{48}

Tab. 3 shows the obtained values of the output parameters combined with the planning matrix of the experiment according to a composite second-order B-plan in normalized and natural designation of variable factors.

Table 3. Results of a two-factor experiment.

Experiment number	x_1	X_1, d_{sd}, %	x_2	X_2, d_{as}, %	Y_1, ρ, kg/m^3	Y_2, *W*, %	Y_3, σ_{cf}, MPa	Y_4, A_s, %
1	-1	17	-1	0	457,0	24,6	2,5	6,3
2	+1	37	-1	0	449,6	25,1	1,2	6,9
3	-1	17	+1	25	582,8	17,7	2,3	1,4
4	+1	37	+1	25	566,5	18,2	1,3	2,1
5	-1	17	0	12,5	519,9	21,1	2,4	3,8
6	+1	37	0	12,5	503,7	21,6	1,4	4,5
7	0	27	-1	0	453,4	24,8	1,8	6,6
8	0	27	+1	25	574,7	17,9	1,9	1,7

A mathematical description of the dependence of standardized by GOST 19222-84 physical-mechanical characteristics of sawdust slag concrete (density, humidity, strength, sorption moisture) on the variable technological parameters is presented in the form of a standardized regression equation:

- density, (Y1, ρ), kg/m3:

Y1 = 511,785 – 6,64x1 + 60,6667x2 – 0,075x21 + 2,175x22 – 2,225x1x2

- humidity, (Y2, W), %:

Y2 = 21,3 + 0,25x1 – 3,45x2 – 0,05x21 + 0,05x22

- strength, (Y3, **σcf**), MPa:

Y3 = 1,9 – 0,5833x1 – 0,0167x2 – 0,05x21 – 0,056x22 + 0,056x1x2

- sorption moisture, (Y4, As), %:

Y4 = 4,125 + 0,3333x1 – 2,4333x2 + 0,025x21 + 0,025x22 + 0,025x1x2

After evaluating the significance of the regression coefficients and conversion the factors to the natural values, the equations of the response functions take the following form:

- density, kg/m3:

ρ = 464,7841 – 0,402* dsd + 4,9859*das – 0,0007* dsd2 + 0,0139*das2 – 0,0178*dsd *das

- humidity, %:

W = 24,634 – 0,002*dsd – 0,284*das

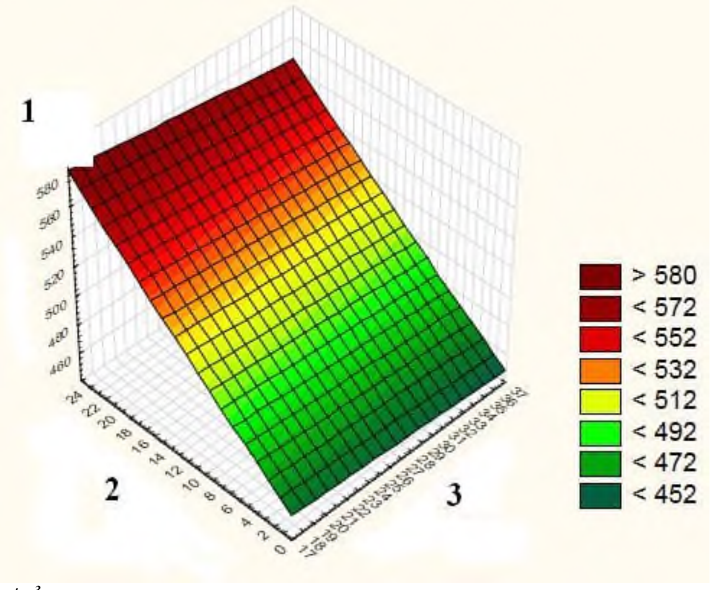
- compressive strength, MPa:

σcf ,= 3,2122 – 0,0363*dsd – 0,0003*das2 + 0,0004*dsd*das

- sorption moisture, %:

As = 5,998 + 0,0173*dsd – 0,2041*das

Based on the obtained regression equations, dependency graphs were created. A graph of the density of sawdust slag concrete on the proportion of sawdust and ash-slag mixture in the composition is shown in Fig. 1.



1 - Density, ρ, kg/m ^{3}
2 - The proportion of ash-slag mixture from the volume of lime in the composition, %
3 - The proportion of sawdust in the composition, %

Fig. 1. Graph of the density of sawdust slag concrete on the proportion of sawdust and ash-slag mixture in the composition.

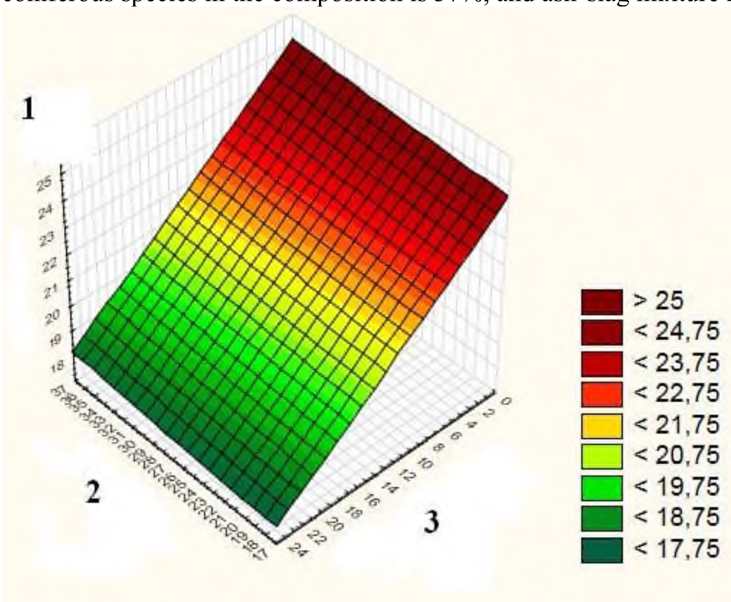
According to GOST 19222-84, the density of heat-insulating sawdust concrete of grade M10 should be in the range from 450 to 500 kg/m3. Based on the data obtained, it is possible to judge the compliance of the quality of the tested samples with the requirements of GOST.

The minimum density of sawdust slag concrete of the proposed composition (449.6 kg/m3) is observed when the proportion of wet sawdust of coniferous species in the composition is 37%, and ash-slag mixture is absent. The maximum density of sawdust slag concrete (582.8 kg/m3) is achieved when the proportion of wet sawdust of coniferous species in the composition is 17%, and the proportion of ash-slag mixture is 25%.

The dependence of the moisture content of sawdust slag concrete on the proportion of sawdust and ash-slag mixture in the composition is shown in Fig. 2.

According to GOST 19222-84, the humidity of heat-insulating sawdust concrete of grade M10 should not exceed 25%. Based on the data obtained, it is possible to judge the compliance of the quality of the tested samples with the requirements of GOST.

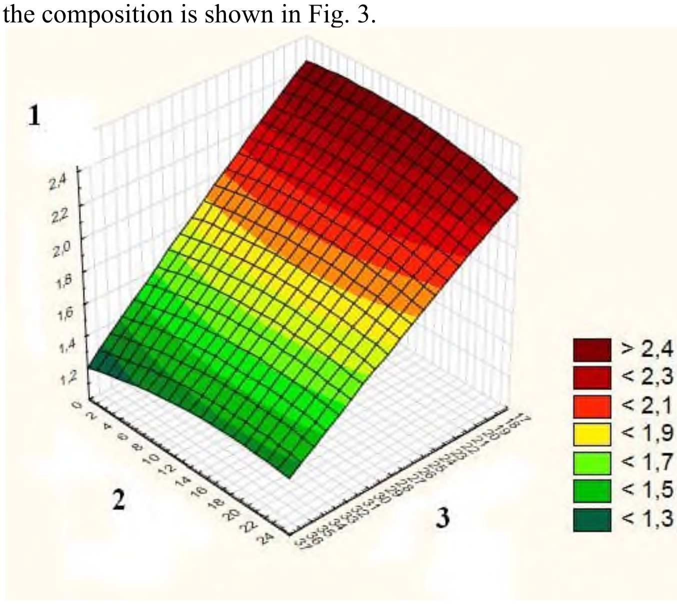
The minimum moisture content of sawdust slag concrete of the proposed composition (17.7%) is observed when the proportion of wet sawdust of coniferous species in the composition is 17%, and the proportion of ash-slag mixture is 25%. The maximum moisture content of sawdust slag concrete (25.1%) is achieved when the proportion of wet sawdust of coniferous species in the composition is 37%, and ash-slag mixture is absent.



1 - Humidity, %
2 - The proportion of sawdust in the composition, %
3 - The proportion of ash-slag mixture from the volume of lime in the composition, %

Fig. 2. Graph of the moisture content of sawdust slag concrete on the proportion of sawdust and ash-slag mixture in the composition.

The dependence of sawdust slag concrete strength on the proportion of sawdust and ash-slag mixture in the composition is shown in Fig. 3.



1 - Strength, MPa

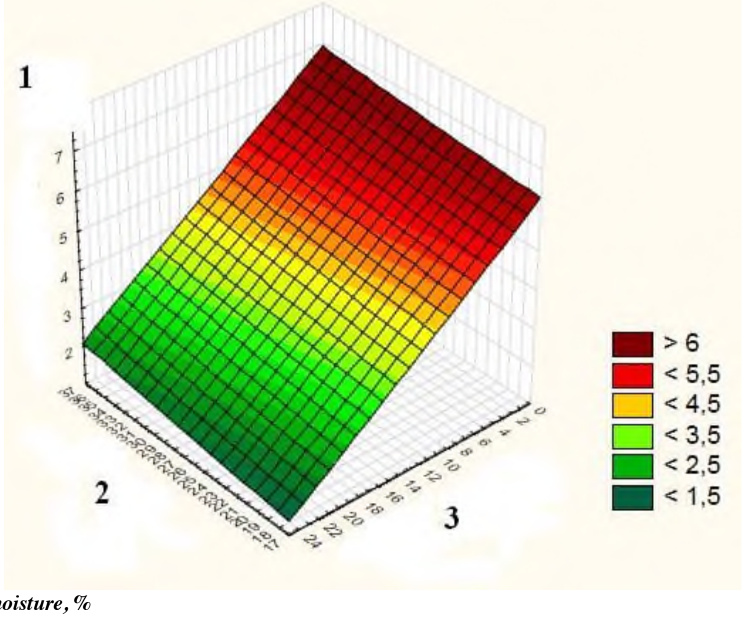
2 - The proportion of ash-slag mixture from the volume of lime in the composition, %
3 - The proportion of sawdust in the composition, %

Fig. 3. Graph of the strength of sawdust slag concrete on the proportion of sawdust and ash-slag mixture in the composition.

According to GOST 19222-84, the strength of heat-insulating sawdust concrete of grade M10 should be in the range from 1.5 to 2.5 MPa. Based on the data obtained, it is possible to judge the compliance of the quality of the tested samples with the requirements of GOST.

The minimum strength of sawdust slag concrete of the proposed composition (1.2 MPa) is observed when proportion of wet sawdust of coniferous species in the composition is 37%, and ash-slag mixture is absent. The maximum strength of sawdust slag concrete (2.5 MPa) is achieved when the proportion of wet sawdust of coniferous species in the composition is 17%, and ash and slag mixture is absent.

A graph of the dependence of the sorption moisture of the samples on the proportion of sawdust and ash-slag mixture in the composition is shown in Fig. 4.



1- Sorption moisture, %
2 - The proportion of sawdust in the composition, %
3 - The proportion of ash-slag mixture from the volume of lime in the composition, %

Fig. 4. Graph of the sorption moisture of sawdust slag concrete on the proportion of sawdust and ash-slag mixture in the composition.

According to GOST 19222-84, the sorption moisture of heat-insulating sawdust concrete of grade M10 should be in the range from 4 to 8%. Based on the data obtained, it is possible to judge the compliance of the quality of the tested samples with the requirements of GOST.

The minimum sorption moisture content of sawdust slag concrete of the proposed composition (1.4%) is observed when the proportion of wet sawdust of coniferous species in the composition is 17%, and the proportion of ash-slag mixture is 25%. The maximum sorption moisture content of sawdust slag concrete (6.9%) is achieved when the proportion of wet sawdust of coniferous species in the composition is 37%, and ash-slag mixture is absent.

4 Conclusions

1. The minimum density of sawdust slag concrete of the proposed composition (449.6 kg/m3) is observed when the proportion of wet sawdust of coniferous species in the composition is 37%, and ash-slag mixture is absent. The maximum density of sawdust slag concrete (582.8 kg/m3) is achieved when the proportion of wet sawdust of coniferous species in the composition is 17%, and the proportion of ash-slag mixture is 25%.

2. The minimum moisture content of sawdust slag concrete of the proposed composition (17.7%) is observed when the proportion of wet sawdust of coniferous species in the composition is 17%, and the proportion of ash-slag mixture is 25%. The maximum moisture content of sawdust slag concrete (25.1%) is achieved when the proportion of wet sawdust of coniferous species in the composition is 37%, and ash-slag mixture is absent.

3. The minimum strength of sawdust slag concrete of the proposed composition (1.2 MPa) is observed when proportion of wet sawdust of coniferous species in the composition is 37%, and ash-slag mixture is absent. The maximum strength of sawdust slag concrete (2.5 MPa) is achieved when the proportion of wet sawdust of coniferous species in the composition is 17%, and ash and slag mixture is absent.

4. The minimum sorption moisture content of sawdust slag concrete of the proposed composition (1.4%) is observed when the proportion of wet sawdust of coniferous species in the composition is 17%, and the proportion of ash-slag mixture is 25%. The maximum sorption moisture content of sawdust slag concrete (6.9%) is achieved when the proportion of wet sawdust of coniferous species in the composition is 37%, and ash-slag mixture is absent.

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