



Optimization of Parameters for the Production of Gypsum Binders Based on Gypsum-Containing Waste

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Abstract. Gypsum-containing wastes are a promising source of raw materials for the production of gypsum binders. However, they have specific features that require the development of alternative approaches and technological regimes in order to ensure the high quality of the final product. The purpose of the article was to study the influence of moisture content of gypsum-bearing waste and firing temperature on the specific surface of the gypsum binder, as well as the compressive strength and average density of gypsum paste based on it. The gypsum-bearing material was citrogypsum. It is a waste product of the biochemical synthesis of citric acid. The experiment was carried out using the method of mathematical planning. Burning of citrogypsum was carried out in a laboratory oven according to a given temperature regime. Using the statistical computer processing of experimental data, regression equations were obtained; graphic dependence as nomograms are constructed; the influence of variable factors on the controlled parameters was assessed. It has been established that the optimal, from the standpoint of energy consumption, is the binder burning at a temperature of 150 °C and the lowest possible raw material moisture content of 5%. Increasing the burning temperature above 150 °C is not economically workable and adversely affects the compressive strength of the gypsum stone, as well.

Keywords: Gypsum-bearing waste · Cytrogypsum · Mathematical experiment planning

1 Introduction

Gypsum-bearing waste (GBW) from various industrial enterprises such as phosphogypsum, FGD gypsum, citrogypsum, etc., is a promising raw material for the production of gypsum binders and can be used as an excellent alternative to natural gypsum. The possibility of obtaining gypsum binders based on GBW has been proven by many studies conducted throughout the world [1–7]. However, it should be noted that it is practically impossible to obtain a high-quality binder based on gypsum-bearing waste using standard technological approaches. This is due to the specifics and significant differences between gypsum-bearing waste and natural gypsum. For example, gypsum-bearing waste is characterized by high humidity, high specific surface area, and a lot of impurities. All this makes it necessary to develop new technological methods and make adjustments to existing ones, taking into account the features of the GBW used [3, 8–10]. In this connection, the purpose of this article was to study the influence of the moisture content of gypsum-bearing waste (citrogypsum) and the burning temperature on the specific surface of the gypsum binder, as well as the compressive strength and average density of the gypsum paste based on it [11–15].

2 Materials and Methods

The object of the study was citrogypsum. This is a gypsum-bearing waste, which is a by-product in the biochemical synthesis of citric acid (Belgorod, Russia) [16].

The experiment was carried out using the method of mathematical planning. The burning temperature of citrogypsum (150–250 °C, with a variation interval of 50 °C) and the moisture content of citrogypsum (0–10 wt%, variation interval of 5%) were chosen as variable parameters (Table 1). Burning of citrogypsum was carried out in a laboratory oven. The curing time for GBW in the oven at the set temperature (150, 200, and 250 °C) was 30 min.

Table 1 Conditions for the mathematical planning of the experiment

Input parameter		Variability range			Unit variation
Origin form	Coded form	– 1	0	1	
Burning temperature, °C	X ₁	150	200	250	50
Humidity, % by wt	X ₂	0	5	10	5

Using the experimental design conditions (Table 1), an experiment design matrix was developed that includes 9 different mixes of citrogypsum-based binder (Table 2).

According to the planning matrix (Table 2), the 9 mixes of citrogypsum-based binder were molded. The output parameters for determining the effect of variable input parameters were the specific surface area (SSA), average density and compressive strength of the gypsum paste. The compressive strength of the gypsum paste was determined for sample cubes 3 × 3 × 3 cm in size, molded at an equal “water-hard” ratio (W/S = 0.4).

Table 2 Experiment design matrix

	Input parameter			
	X ₁		X ₂	
1	– 1	150	– 1	0
2	– 1	150	+ 1	10
3	– 1	150	0	5
4	+ 1	250	– 1	0
5	+ 1	250	+ 1	10
6	+ 1	250	0	5
7	0	200	– 1	0
8	0	200	+ 1	10
9	0	200	0	5

3 Results and Discussions

After statistical computer processing of experimental data, regression equations (Eqs. 1–3) were obtained. Based on the equations, graphical dependencies were plotted that allow assessing the effect of varying input parameters (Figs. 1, 2 and 3) on controlled output parameters.

$$SSA = 330.1 + 5.217 \cdot X_1 + 2.0667 \cdot X_2 + 39.42 \cdot X_1^2 + 5.367 \cdot X_2^2 - 1 \cdot X_1 \cdot X_2 \quad (1)$$

$$R_{comp} = 4.479 - 0.668 \cdot X_1 - 0.293 \cdot X_2 - 0.168 \cdot X_1^2 - 0.26 \cdot X_2^2 + 0.59 \cdot X_1 \cdot X_2 \quad (2)$$

$$P_{average} = 1028 - 4.933 \cdot X_1 + 1.1333 \cdot X_2 + 13.2 \cdot X_1^2 - 16.3 \cdot X_2^2 - 0.8 \cdot X_1 \cdot X_2 \quad (3)$$

The nature of the presented graphical dependence as monograms (Fig. 1) showed that an increase in humidity and burning temperature contributes to an increase in the specific surface of the citrogypsum-based binder. There is a decrease in the specific surface area in the entire humidity range for citrogypsum-based binders obtained at a temperature of 200 °C.

The maximum compressive strength is observed for citrogypsum-based binder mixes obtained at a burning temperature of 150 °C and humidity up to 5%. A further increase in temperature leads to a decrease in compressive strength. This is most likely due to the formation of a larger amount of anhydride, which has a higher porosity and lower compressive strength vs. calcium sulfate hemihydrate. It should be noted that the gypsum paste obtained on this mix of citrogypsum-based binder is characterized by the maximum values of the average density (Fig. 2).

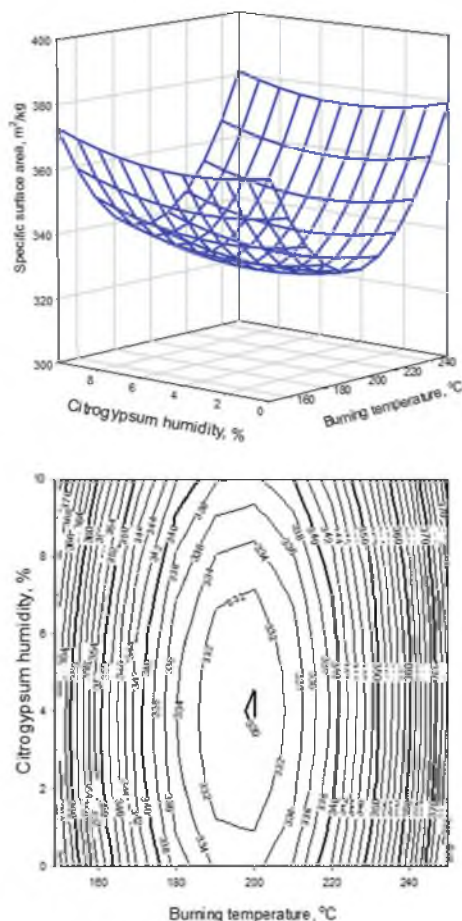


Fig. 1 Dependency of the specific surface area of the gypsum binder on the humidity of the citrogypsum and the burning temperature

With an increase in the initial humidity above 5%, I also observed a decrease in the compressive strength of the gypsum paste. This can be explained by an increase in the porosity of the binder particles due to evaporation and removal of water as steam at high temperature (Fig. 3).

The minimum values of the average density are typical for samples of citrogypsum-based binding paste, which has the minimum specific surface area, which is quite natural.

4 Conclusion

Based on the results obtained, the following conclusions are proposed:

- optimal, in terms of energy consumption, is the burning of the binder at a temperature of 150 °C and the lowest possible raw material moisture content of 5%;

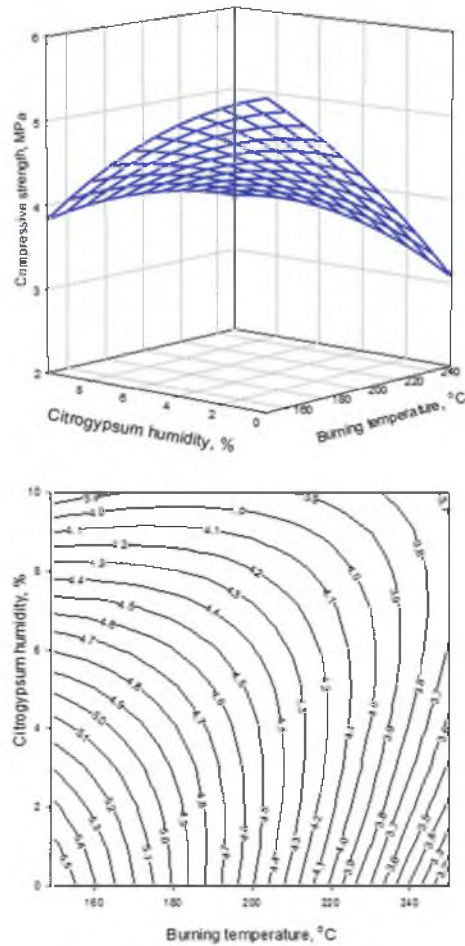


Fig. 2 Dependency of compressive strength of gypsum paste on citrogypsum humidity and burning temperature

- Increasing the burning temperature above 150 °C is not economically feasible, and adversely affects the compressive strength of the citrogypsum-based binding paste, as well.

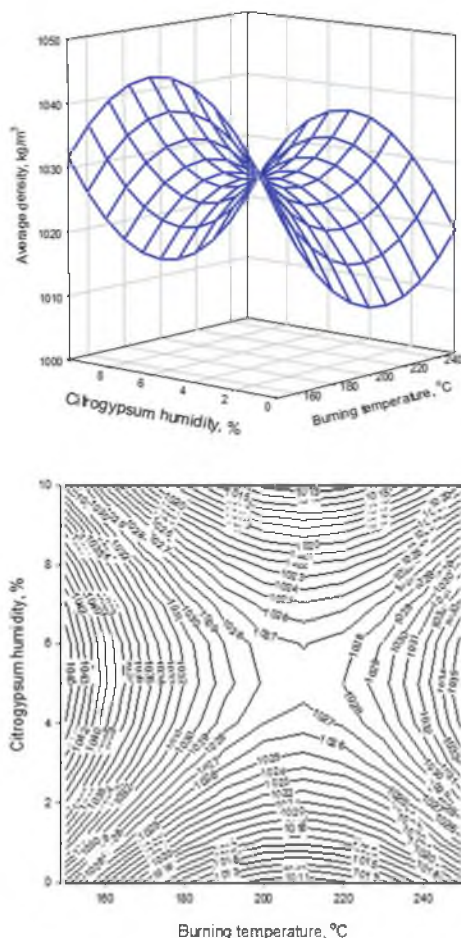


Fig. 3 Dependency of average density of gypsum paste on citrogypsum humidity and burning temperature

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