

IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

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To cite this article: E A Shkarpetkin and A V Osokin 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **560** 012044

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Process of granulating perlite-containing mixtures: experimental study

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Abstract. The article presents results of the experimental studies concerning the effect of technological parameters on the process of forming perlite-containing mixtures as well as physical and mechanical properties of granules based on them.

1. Introduction

Searching for solutions to the effective use of waste from various industries is still challenging and urgent. However, the most common impediments to the sustainable development of waste recycling are: high labor complexity of sorting, especially mixed, waste into separate ingredients, the need for cleaning, washing and disinfection, checking for the presence of hazardous materials; high energy consumption for their crushing and production of secondary raw materials or semi-finished products; reduced productivity of equipment due to insufficient study of the properties of processed materials [1-5].

With this in mind, it is of great interest to find efficient ways of effective disposal and recycling of waste, namely, powders (dust) formed as a result of firing in the production of cement, lime, expanded perlite, vermiculite, etc. These materials are already in the ground state and contain a minimum number of foreign inclusions and can be used for manufacturing building materials, for example, granular thermal insulation aggregates for concrete [6-8].

2. Methodology of the experimental studies

Manufactured porous heat-insulating fillers are characterized by low bulk density and low thermal conductivity. In many respects the properties of different types of these fillers are determined by charge forming peculiarities, and by the presence of special additives introduced into the composition.

For experiment, we used composition based on production waste of the expanded perlite sand. Bentonite, gypsum and liquid glass were selected as additives for granules.

The main ingredient in the composition is off-specification particles (dust) resulted in the production of expanded perlite sand, which has a high specific surface area of particles ($S = 7200 \text{ m}^2/\text{kg}$) and molecular moisture capacity (up to 70 %) [8].

The task of experimental studies was to determine the effect of moisture and densifying coefficient of perlite-containing mixture on characteristics of the granules (bulk density – ρ_{bulk} kg/m^3 , a cylinder compressive strength – σ_{com} , MPa, and the number of on-specification granules – q , %).

Method of obtaining granules included preparation of ingredients, their mixing, determination of bulk density of the mixture and its densifying in the roll-type device. The densifying coefficient was



calculated as the ratio of the obtained density to the initial density of the mixture ($C_{\text{dens}} = p_i/\rho_0$, where p_i is the density of the mixture after the roll device and ρ_0 is the density of the initial mixture, kg/m^3) [9]. Mixture formation in a vibration-centrifugal granulator was one of the conditions of the experiment (Figure 1) [10].

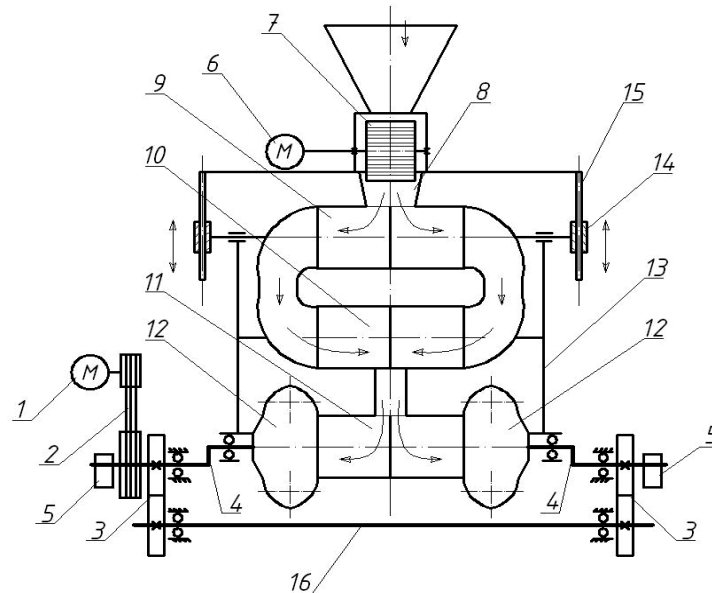


Figure 1. Design scheme of the granulator.

The granulator starts from motor 1 of the main drive. From V-belt transmission 2 and gear pairs 3, rotation is transmitted to the eccentric roller 4, with installed counterweights 5 on both sides of it. The movable frame 13 is connected to eccentric shaft, sliders 14 and working drums 9, 10 and 11. With rotational movement of eccentric shaft 4, each of drums 9, 10 and 11 fixed on movable frame 13 moves on a given trajectory: upper drum 9 – reciprocating motion in the vertical plain surface, middle drum 10 – on an ellipsoidal trajectory, lower drum 11 – with toroidal chambers 12 – on a circular trajectory. Individual electric drive 6 rotates densifying roll 7. Reciprocating motion of the frame 13 vibrates chute 8.

This unit provides following technological operations:

- removal of gaseous phase from the moistened powder mixture (densifying);
- vibration hardening of granulate being formed, its transportation and classification (in the upper drum);
- vibration-centrifugal forming and hardening of granulate in waterfall-cascade mode (in the middle drum);
- centrifugal forming and hardening of granules in cascade mode (in the lower drum);
- surface hardening of the obtained granulate (in toroidal chambers) [8, 9].

Obtained granules were sifted according to particle size (-2 mm, $2-7$ mm and $+7$ mm), they were dried in a drying unit at a temperature of 200 °C. Then the compressive strength of the layer of granules and their bulk density were determined.

3. Analysis of experimental results

The analysis of the obtained dependences (Figure 2) shows that the granulation process can be considered steady at humidity $W = 52-56$ %. In this range, the values of the output parameters are the closest, the deviations do not exceed 5 %. The extremes of the graphs ($p_{\text{bulk}} = 340-330$ kg/m^3 , $\sigma_{\text{com}} = 1.0$ MPa, $q = 70$ %) correspond to the humidity value $W = 54$ %.

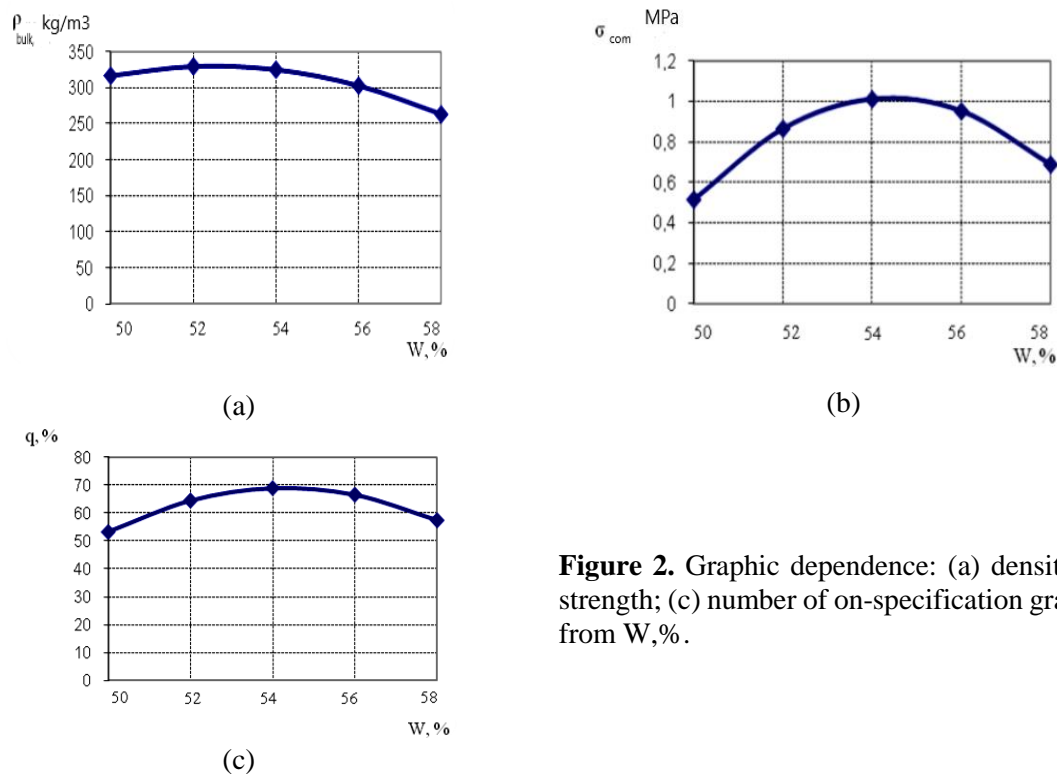


Figure 2. Graphic dependence: (a) density; (b) strength; (c) number of on-specification granules from W, %.

With an increase in humidity from 52% to 54%, there is a slight decrease in the bulk density of dry granules from 340 kg/m³ to 330 kg/m³. A further increase in humidity from 54% to 58% leads to a decrease in all values of output parameters. Excessive moistening of the mixture causes it, leading to the formation of agglomerates larger than $d_{\text{gr}} > 10$ mm and the adhesion of small granules with a size of 1.5-3 mm.

A change in the moisture content of the charge downwards from 50% is not reasonable, since at lower values of humidity there is a significant decrease in strength ($\sigma_{\text{com}} \leq 0.4$ MPa) and the amount of on-specification product ($q \leq 40$ %).

To study the effect of humidity in combination with the densifying coefficient ($C_{\text{dens}} = 1.5-3.5$) authors studied experimentally their pair effect on the granule characteristics. The results are presented as surfaces built on three coordinates at constant values of other factors (Figure 3).

Graphs show that the interaction of studied factors has a significant impact on all characteristics of the granules, namely, it leads to an increase in their compressive strength, density and outcome of on-specification product. In this case, to a greater extent, the densifying coefficient affects the density and strength of the granules.

At the same time, increasing the values of output parameters is not always positive. Thus, the increase in the bulk density of granules (in case of thermal insulation fillers manufacturing) worsens their consumer properties.

Best indicators $\rho_{\text{bulk}} = 300$ kg/m³, $\sigma_{\text{com}} = 1.2$ MPa, $q > 70$ % are observed when humidity is $W = 52-54$ %, and values are $C_{\text{dens}} = 2.5-3$, and the obtained granules meet the requirements for artificial porous fillers (State Standard GOST 32496-2013) and can be used for manufacturing of building materials and products.

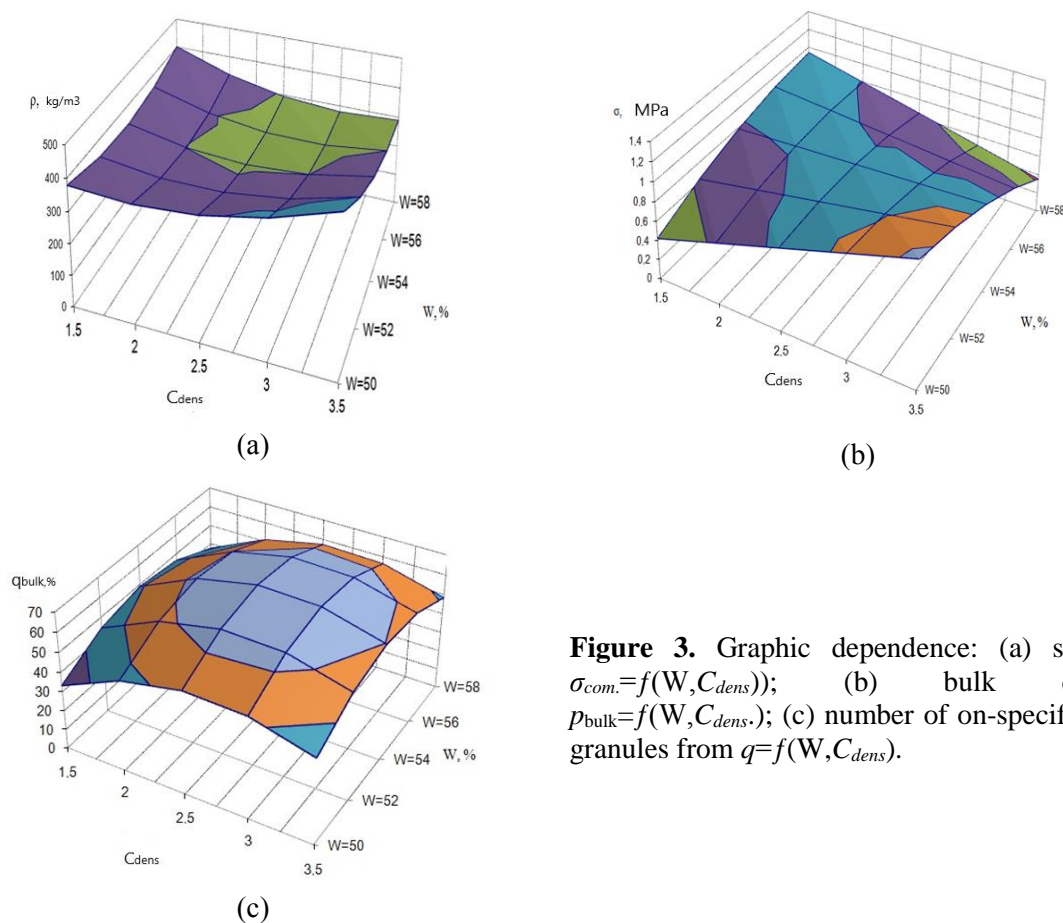


Figure 3. Graphic dependence: (a) strength $\sigma_{com}=f(W, C_{dens})$; (b) bulk density $\rho_{bulk}=f(W, C_{dens})$; (c) number of on-specification granules from $q=f(W, C_{dens})$.

4. Conclusion

Thus, the experimental studies result in more reasonable approach to the selection of rational parameters for the granulation process of perlite-containing mixtures and can find practical application in solving one of the urgent problems associated with the utilization and recycling of powdered technogenic materials.

Acknowledgments

The article was prepared within the development program of the Flagship Regional University on the basis of Belgorod State Technological University named after V G Shoukhov, using equipment of High Technology Center at BSTU named after V G Shoukhov.

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