EFFECT OF TEMPERATURE, STORAGE TIMES, AND STRESS STATE ON THE
CAKING OF BULK MATERIALS

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Results are reported from experimental studies of the susceptibility of bulk materials to caking in relation to temperature conditions, storage times, and the stress state of the material.

Several investigations [1, 2] have evaluated the susceptibility of finely dispersed bulk materials to caking by adopting a physical quantity $\tau_0$ which characterizes the initial unit resistance to shear with stress removed, i.e., at $\sigma = 0$.

The cakeability of finely dispersed bulk materials is affected by the storage time $B$, the moisture content of the material $W$, and the prestress state $\sigma_{\text{con}}$ of the material [1-5].

However, it must be noted that the consolidation process is also significantly affected by temperature conditions and the granulometric and granulomorphological composition of the material and external factors such as vibration and aeration.

The regulation GOST 21560.4-76-21560.5-76 [3] is used to evaluate the cakeability of fertilizers. The regulation is used to determine the strength of briquettes produced in special molds under certain conditions. Methods based on crushing of specimens were proposed in [4, 5] to determine the causes of consolidation. These methods can be used only for highly compacted materials such as mineral fertilizers, in which agglomerates are formed.

Bulk materials do not always form strong agglomerates in the food, chemical, mining, and other industries. Thus, the initial unit resistance to shear $\tau_0$ is used to determine the factors which affect consolidation.

We propose to study the effect on cakeability of the ambient temperature $T$ (K) and storage time $B$ (days), with a fixed stress state $\sigma_{\text{con}}$, fixed initial moisture $W$, and fixed granulometric and granulomorphological composition $d_i$. We studied both inorganic and organic materials: kaolin, concentrated at $W = 0.60\%$ and $d_a = 11.70 \mu m$; chalk at $W = 0.5\%$ and $d_a = 9.87 \mu m$; flour of grade 1 at $W = 13.00\%$ and $d_a = 45 \mu m$; wheat groats at $W = 10.75\%$ and $d_a = 750 \mu m$ (more details on the characteristics of the materials are given in [8]). The studies were conducted at an ambient temperature $t = 22 \pm 1^\circ C$ and a relative humidity of 75%.

Results of determination of the cakeability of the above materials as a function of temperature $T$ (258-308 K) and storage time $B$ (from 1 to 5 days), with a constant prestress $\sigma_{\text{con}} = 30$ kPa and an initial moisture content $W = \text{const}$, are shown in Fig. 1. It can be seen from...
Fig. 1. Dependence of unit initial resistance to shear \( \tau_0 \) (kPa) on temperature \( T \) (K) and storage time \( B \) (days) for inorganic (a - chalk; b - concentrated kaolin) and organic (c - grade-I flour; d - wheat groats) materials.

the data that the initial unit resistance to shear \( \tau_0 \) increases with an increase in storage time, which is evidence of consolidation of the material.

A change in temperature from 258 to 308 K is accompanied by a nonuniform change in shear resistance. Meanwhile, all of the materials studied form a saddle-shaped consolidation surface \( \tau_0 = f(B, T) \), the minimum of which passes through \( T = 273.15 \) K.

An increase in the temperature of the materials for different storage times is accompanied by an increase in initial shear resistance \( \tau_0 \). The greatest consolidation is seen for the kaolin, while the least is seen in the case of the wheat groats.

The increase in consolidation of the materials with temperature and storage time is explained by strengthening of the contacts between particles due to the removal of moisture with an increase in temperature, cementation of the particles, and other processes.

The dissimilar changes in initial unit resistance to shear with an increase in \( B \) and \( T \) for the test materials is attributable to differences in their granulometric and granulomorphological composition and the nature of the materials.

An increase in caking is also seen with a decrease in temperature from 273.15 to 258 K for different storage times (1-5 days). The absolute value of the consolidation which occurs with a decrease in temperature and increase in storage time is \( \tau_{0,\text{max}} = 5.71 \) kPa for the kaolin and \( \tau_{0,\text{max}} = 2.81 \) kPa for the wheat groats. This increase in \( \tau_0 \) is due to the transition of crystallization bridges formed between particles from the liquid state to the solid state, i.e., freezing.

The experimental data was analyzed on an ES 1022 computer. It yielded the following relations for consolidation processes:

for concentrated kaolin \( \tau_0 = 4.2096 + 0.2323B + (15.7783B - 112.3932)(-0.8548 + 0.61 \times 10^{-2}T - 10^{-5}T^2)B \) at \( R = 0.94 \);

for chalk \( \tau_0 = 3.3204 + 0.2474B + (0.78 \times 10^{-2} - 0.11 \times 10^{-2}B)(11840.9 - 83.26T + 0.1459T^2)B \) at \( R = 0.97 \);

for grade-I flour \( \tau_0 = 2.7168 + 0.1517 + (9.3783B - 69.71)(-0.8272 + 0.58 \times 10^{-2}T - 10^{-5}T^2)B \) at \( R = 0.97 \);