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1963

SovietRxiv

Abstract

Full Text

PHYSICAL CHEMISTRY

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EFFECT OF PARTICLE ORIENTATION ON THE STRUCTURAL-MECHANICAL PROPERTIES OF PALYGORSKITE PASTES

(Presented by Academician P. A. Rebinder, January 5, 1963)

A very widespread method, especially in technology, for regulating the properties of clay pastes is mechanical treatment. As a result of such treatment, an anisotropic structure is formed within the volume of the articles, the structural features of which must correspond to the specified technological parameters. The mineral palygorskite, which has a fibrous or needle-like crystal structure, is of particular interest for studying the effect of particle orientation ([1]) on changes in the structural-mechanical properties of its aqueous pastes.

To obtain an oriented arrangement of particles, a paste of palygorskite from the Cherkassy deposit ([2]) (Fig. 1) was subjected to rolling. Samples for studying its mechanical properties in undisturbed structures were prepared so that in one of them the direction of deformation coincided with the plane of rolling (X, Y), while in the other it was perpendicular to it (the Z axis). As a result of the treatment, a considerable number of palygorskite particles became arranged in the volume of the paste with their largest axes parallel to the rolling plane, creating an anisotropic structure. Measurements of the elastic-plastic-viscous constants ([3]) of this structure showed (Table 1) that in the sample in which shear deformation developed

Table 1

Palygorskite paste	Moisture, %	$E_1 \times 10^{-6}$, dyn/cm^2	$E_2 \times 10^{-6}$, dyn/cm^2	$\eta_1 \times 10^{-8}$, poise	$P_{k1} \times 10^{-4}$, dyn/cm^2	λ	$P_{k1}/\eta_1 \times 10^6$, sec^{-1}	θ_1, sec	$N_\varepsilon^{\text{cond}} \times 10^{-5}$, erg/sec
Particles not oriented	51.0	190	115	275	8.2	0.624	2.98	90	295

Palygorskite paste	Moisture, %	$E_1 \times 10^{-6}$, dyn/cm^2	$E_2 \times 10^{-6}$, dyn/cm^2	$\eta_1 \times 10^{-8}$, poise	$P_{k1} \times 10^{-4}$, dyn/cm^2	λ	$P_{k1}/\eta_1 \times 10^6$, sec^{-1}	θ_1, sec	$N_\varepsilon^{\text{cond}} \times 10^{-5}$, erg/sec
Direction of deformation parallel to the plane X, Y	51.0	60	133	900	5.5	0.310	0.611	466	286
Direction of deformation perpendicular to the rolling plane (axis Z)	51.0	73	138	630	11.3	0.346	1.800	298	278

parallel to the plane X, Y, there occurred, in comparison with the unoriented sample, a considerable decrease in the conditionally instantaneous modulus of elasticity E_1, the conditional static yield limit P_{k1}, and an increase in the highest plastic viscosity η_1. This led to a decrease in the elasticities λ and plasticity P_{k1}/η_1, and to an increase in the period of true relaxation θ_1.

As a result of these changes in the structural-mechanical constants, the palygorskite paste with particle orientation in planes parallel to the plane of shear passed from the fifth ([4]) to the third structural-mechanical type (Fig. 2).

In the sample that was subjected to deformation in the direction of the Z axis, i.e., in the direction perpendicular to the rolling plane, there took place, analogous to the first sample with the direction of deformation parallel to⋯

Fig. 1

Figure 1: Fig. 1

Fig. 2

Figure 2: Fig. 2

the rolling plane, a change in the value of the conventional instantaneous modulus of elasticity E_1, which led to an increase in the elasticity of the system. However, under deformation in the direction of the Z axis, the conventional static yield point P_{k1} increased substantially and the greatest plastic

Fig. 1. Electron-microscopic photograph of palygorskite from palygorskite clay of the Cherkassy deposit

viscosity η_1 decreased. In the system the plasticity P_{k1}/η_1 increased and the period of true relaxation θ_1 decreased. A palygorskite paste with particle orientation in a plane perpendicular to the direction of shear deformation passed from the fifth to the fourth structural-mechanical type; at the same time, it developed significantly greater (by 17-28%) plastic deformations and acquired a twofold greater conventional static yield point P_{k1}.

The change in the structural-mechanical type of the palygorskite paste as a result of particle orientation (Fig. 2) occurs only through an increase in elastic and a decrease in plastic deformations, with practically no change in the magnitudes of elastic deformations (17.8%–21.6%–20.2%).

When comparing the values of the conventional deformation power $N_{\varepsilon\,\text{cond}}(4)$ for unoriented and oriented samples of palygorskite pastes, one can be convinced that particle orientation leads to a certain increase in the forces of molecular interaction.

Fig. 2. Development of deformations of palygorskite pastes in specimens: 1 –with unoriented structure; 2 –with a structure oriented parallel to the direction of deformation; 3 –with a structure oriented perpendicular to the direction of deformation. Relative deformations: ε_0' –elastic, conventional instantaneous; ε_2' –elastic, $\varepsilon_1'\tau$ –plastic, where $\tau = 1000$ sec.

Thus, the volumetric anisotropy of the structure of a palygorskite paste with an oriented arrangement of the mineral fibers in planes parallel to the rolling plane, in comparison with an unoriented structure, is characterized by a certain increase in the number of contacts between pa-

particles owing to their favorable arrangement within the volume of the paste, which makes the system more elastic and less highly plastic. At the same time, when the system is deformed along planes with an oriented arrangement of particles, the system becomes more fluid and viscous, since the process of destruction and restoration of bonds during the sliding of fibers past one another, parallel to the planes of preferential arrangement of their major axes, proceeds with insignificant destruction of the particles and with a greater probability of restoration of the bonds due to molecular interaction forces. If, however, the system is deformed in a direction perpendicular to the planes of preferential arrangement of the mineral fibers, the number of ruptures or changes in particle orientation inevitably increases (which is reflected in an increase in P_{k1}), while the probability of rapid restoration of the broken bonds decreases (which determines the decrease in η_1).

The authors express their deep gratitude to Academician P. A. Rebinder for his exceptional attention to the work and valuable advice.

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Received
29 XI 1962

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Note: Figure translations are in progress. See original paper for figures.