EXPERIMENTAL INVESTIGATION OF THE CORRELATION BETWEEN MASS TRANSFER AND CAPILLARY POTENTIALS

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Inzhenerno-Fizicheskii Zhurnal, Vol. 14, No. 4, pp. 731–734, 1968

UDC 631.43

The results of a determination of the mass transfer potential and capillary potential as functions of moisture content are presented, together with empirical formulas relating these potentials for sand and clay soils.

The mass transfer potential in moist soils is usually determined either on the experimental potential scale by the method of contact with a standard material (filter paper) or on the energy potential scale using ceramic probes or tensiometers. The standard method has long been employed in the Soviet Union. It is now also beginning to be used abroad [4, 5]. V. G. Kornev [1] first made use of ceramic probes in 1924. Kornev's instruments, variously modified, are widely used in agrophysical research, especially in England and the United States. In 1960 at the Seventh International Congress of Soil Scientists the terminology committee for soil physics proposed the term "capillary potential" ψ for the mass transfer potential determined with ceramic probes, which characterizes the binding energy of sorption and capillary moisture [3]. In conformity with thermophysical terminology we will call the potential determined by the standard contact method the mass transfer potential and denote it by θ.

Establishing a correlation between ψ and θ would permit the use of experimental material obtained by different methods in studying moisture transport in soils and other colloidal capillary-porous bodies. Luikov [2] has presented data on the relation between potentials for the region of hygroscopic moisture content. He has also determined the capillary potential for filter paper. As for the region of the moist state, McQueen and Miller [4] have obtained a curve without indicating the soils for which it was determined.

We have established a relation between the potentials in the region of the moist state for various soils. The experiments were conducted with Pyzhevskii bentonite ($\gamma_0 = 780$ kg/m^3), Glukhovetskii kaolin ($\gamma_0 = 1100$ kg/m^3), and fine sand ($\gamma_0 = 1500$ kg/m^3) and also with a polymineral clay of undisturbed structure from the "Gershona" deposit (Brest Oblst) ($\gamma_0 = 1300$ kg/m^3). For each soil at 30° C we determined the dependence of the mass transfer potential θ on moisture content (by the contact method) and at the same temperature, using ceramic probes, the relation between moisture content and the potential ψ. The results are presented in Figs. 1 and 2. Then at specific values of the moisture content for each soil we determined values of ψ and θ from the $\psi = f_1(W)$ and $\theta = f_2(W)$ curves and constructed $\theta = f_3(\psi)$ curves (Fig. 3). As can be seen from Fig. 1, for sand, kaolin, and bentonite, as the moisture content increases, so does the capillary potential, at first rapidly, and then slowly, i.e., the $\psi = f_1(W)$ curves are all concave downward. The $\psi = f_1(W)$ curve for the polymineral clay of undisturbed structure is almost a straight line. The mass transfer potential θ (Fig. 2) for clay soils increases slowly at first, then quickly—the curves are concave upward. The mass transfer potential for sand behaves in the same way as the capillary potential. The experiments showed that the correlation curves for the investigated soils do not coincide and are somewhat different in shape (Fig. 3).

The different behavior of the $\theta = f_2(W)$ and $\psi = f_1(W)$ curves and the noncorrespondence of the correlation curves $\theta = f_3(\psi)$ indicate that when the methods in question are employed the different forms of moisture binding energy are taken differently into account.

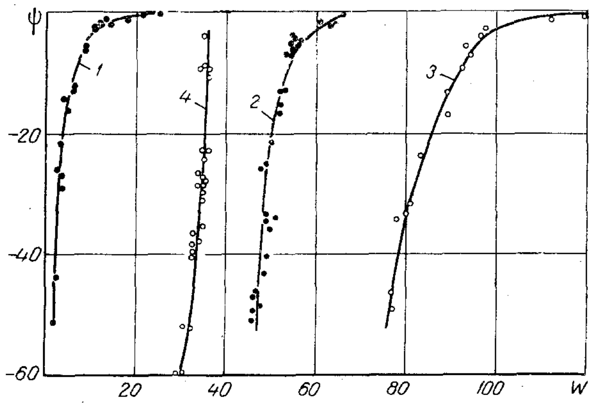

Fig. 1. Capillary potential ψ, J/kg, as a function of the moisture content of the material W, %: 1) fine sand; 2) kaolin; 3) bentonite; 4) polymineral clay of undisturbed structure.

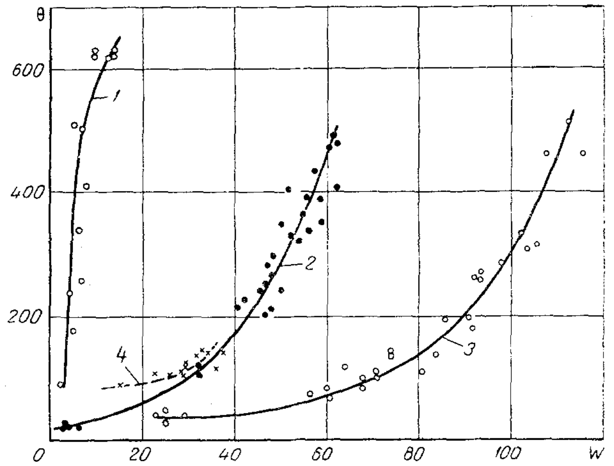

Fig. 2. Mass transfer potential θ as a function of the moisture content of the material W, %: 1) fine sand; 2) kaolin; 3) bentonite; 4) polymineral clay of undisturbed structure.

The relation between the potentials θ and ψ can be described by the following empirical formulas. For sand

$$\theta = \frac{135}{\psi^{0.5}\exp(0.02\psi)}, \quad (1)$$

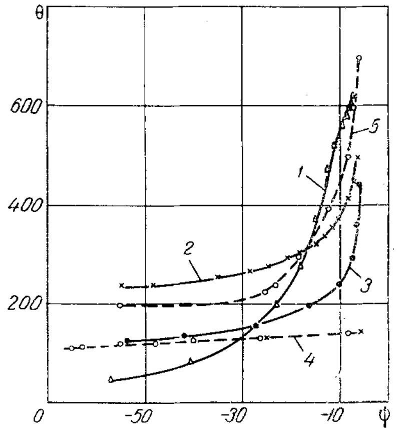

Fig. 3. Correlation curves for the mass transfer potential θ and the capillary potential ψ, J/kg: 1) fine sand; 2) kaolin; 3) bentonite; 4) polymineral clay of undisturbed structure; 5) from data of McQueen and Miller [4].

for kaolin

$$\theta = \frac{544\exp(0.001\psi)}{\psi^{0.24}}, \quad (2)$$

for bentonite

$$\theta = \frac{377\exp(0.002\psi)}{\psi^{0.28}}, \quad (3)$$

for polymineral clay of undisturbed structure

$$\theta = 145 - 0.43\psi. \quad (4)$$

Obviously, further research in this direction will make it possible to obtain corresponding correlation curves for similar soils. It will then be possible to use experimental data obtained by different methods in future soil studies.

NOTATION

W is the moisture content of material; ψ is the capillary potential; θ is the mass transfer potential; γ_0 is the density of dry material.

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20 June 1967

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