INTERRELATION BETWEEN THE STRUCTURAL-SORPTION CHARACTERISTICS AND THE PERMEABILITY OF CERTAIN HYDROPHILIC DISPERSE SYSTEMS

P. P. Olodovskii

Inzhenerno-Fizicheskii Zhurnal, Vol. 14, No. 1, pp. 44–47, 1968

UDC 541.182.6

Experimental results are used to construct a relation between the specific permeability, the effective specific surface per unit volume, and the porosity for a number of clay minerals and soils.

The principal factors determining the permeability of soils are the porosity, the amount of bound water, and the specific surface of the solid phase [1].

However, attempts to find a universal relation between these properties of a porous medium and the permeability of soils in which the particles are bound together in aggregates in various ways [1] have proved unsuccessful.

The present investigation is restricted to natural clays of the kaolinite, illite, and montmorillonite groups: Glukhovetskii kaolin (Vinnitsa Region), Chasov-Yar monothermitic clay (Artemovsk, UkrSSR), Crimean kill Kurtsevskii deposit), Pyzhevskii bentonite (Khmel'nitskii Region), and clay from the "Gershona" deposit (Brest).

Values of the specific permeability were obtained for each specimen at various porosities.

Experimental. The experimental setup (Fig. 1) consisted of vessel 1 with a perforated bottom, in which the specimen was placed, base 3 of this vessel, upper cylinder 2 in which a given water level was maintained by means of sealed-in tube 6, water reservoir 4, filtrate flask 5, thermometer 7, and mounting board 8. Elements 1–5 were made of glass.

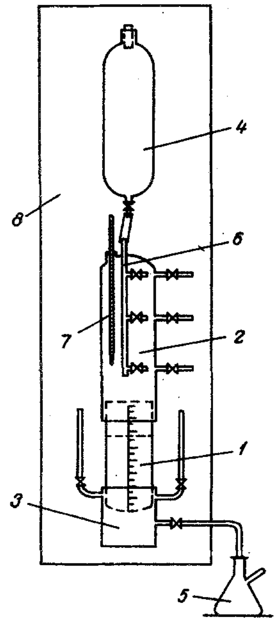

Fig. 1. Diagram of experimental apparatus.

The soil was placed in the apparatus after being moistened and kept under special conditions until the swelling process was complete.

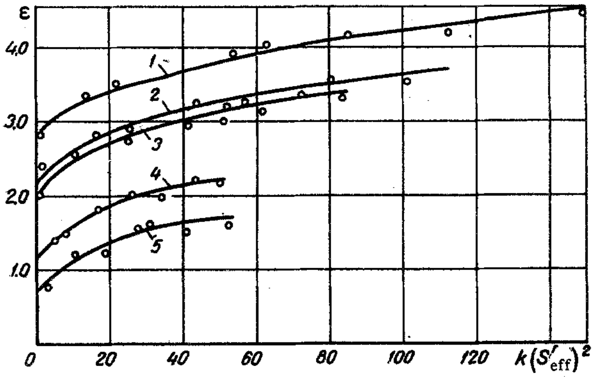

Fig. 2. Relation between specific permeability k, effective specific surface per unit volume S'_{eff} and porosity e for clay soils: 1) Crimean kill; 2) Pyzhevskii bentonite; 3) Chasov-Yar clay; 4) 4) Glukhovetskii kaolin; 5) clay from the "Gershona" deposit.

During each run lasting from 15 to 30 days for the different soils, we measured periodically the amount of filtrate corresponding to a specific time interval and water temperature; the experiment was terminated when the change in the flow of filtrate did not exceed 5–7% over a period of 5–7 days. After each measurement we determined the length of the filtration path, the moisture content, and the porosity of the specimen.

The permeability was found from

$$k = \frac{q\mu L}{\Delta PF}. \tag{1}$$

In our experiments $\Delta P/L$ is the pressure gradient acting on a length L, and amounted to 20 000–30 000 N/m^3, i.e., within the limits of a linear relation between velocity and gravitational filtration gradient.

Analysis of the results. The following relation (Fig. 2, curves 1–5) was obtained between the specific permeability, the porosity, and the effective specific surface per unit volume for all the systems investigated

$$k = \frac{(\varepsilon - \varepsilon_0)^2}{(S'_{eff} m)^2} = \frac{(\varepsilon - \varepsilon_0)^2}{0.025 (S'_{eff})^2}, \tag{2}$$

$$S'_{eff} = S_{eff}\,\delta, \tag{3}$$

for which the statistical scatter of the data did not exceed 5–7%.

Values of S_{eff} used in the calculations are presented in the table. They were obtained from absorbed water density distribution curves [3]. There is a 2–3% difference between these and the values calculated from the integral heats of wetting [2].

Calculated Values of the Maximum Swelling Moisture Content of Clay Minerals Compared with the Amount of Water Not Participating in Gravitational Filtration

Soil	S_{eff}, m^2/g	W from filtration curves, %	W_s from swelling kinetics curves, %
Crimean kill	422.1	100,0	114,3
Pyzhevskii bentonite	477.7	80,0	83.7
Chasov-Yar clay	202.0	60.0	52.7
Glukhovetskii kaolin	76.0	42,8	43,1
Clay from the "Gershona" deposit (Brest)	141.8	25,0	27.0

For clay minerals with an expanding crystal lattice (Crimean kill, Pyzhevskii bentonite) we substituted into Eq. (3) values of S_{eff} for the cleavage surfaces and external basal surfaces of the lattice [3].

The amount of water absorbed by the clay-soil structure $W = d''(\varepsilon_0/d_0)\,100\%$ (d_0 is the soil density and d'' the density of the water) was close to the maximum swelling moisture content of the systems (W_s).

In the table, values of W calculated from the filtration curves (Fig. 2) are compared with W_s determined from the swelling kinetics curves for the clays in water [2].

Clearly, the nature of the bonds that keep part of the water volume out of gravitational filtration is determined, as in swelling, by osmotic and capillary suction forces, and in the case of disperse systems with an expanding crystal lattice (Crimean kill, Pyzhevskii bentonite) by the penetration of water films into the space between lattice planes.

NOTATION

k is the permeability (specific permeability), m^2; q is the filtrate flow rate, m^3/sec; μ is the viscosity coefficient for water, $N \cdot sec/m^2$; L is the filtration path, m; ΔP is the pressure drop across the filtration path, N/m^2; ε is the porosity of the soil; ε_0 is the porosity corresponding to the volume of water not participating in the filtration process (at $\varepsilon = \varepsilon_0$, $k = 0$); S'_{eff} is the effective specific surface of soil per unity volume, 1/m; δ is the density of absolutely dry soil, kg/m^3; S_{eff} is the effective specific surface per unit mass of absolutely dry soil, m^2/kg; m is a coefficient determining the fraction of the specific effective surface per unit volume of the material (S'_{eff}) interacting with the moving liquid. (For all the systems investigated $m = 0.155$.)

REFERENCES

1. B. P. Gorbunov, collection: Mechanics of Soils [in Russian], Gosstroiizdat, no. 43, 1961.
2. F. D. Ovcharenko, Hydrophily of Clays and Clay Minerals [in Russian], izd. AN UkrSSR, 1961.
3. P. P. Olodovskii, collection: Building Thermophysics [in Russian], izd. Energiya, 1966.

12 May 1967 Institute of Water Problems, Minsk