DETERMINATION OF PERCOLATION COEFFICIENT BY MEANS OF TEST WELLS

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A relation is obtained between the percolation coefficient, obtained from individual test pumpings, and the difference of level at the edge of the drain; a method (EHDA) of calculating perturbing drains and determining bed parameters is proposed.

There are two test methods of determining the percolation coefficient by means of pumping from a cluster of wells under steady-state conditions: from observation wells (method 1) and from observation wells in combination with a perturbing well (method 2).

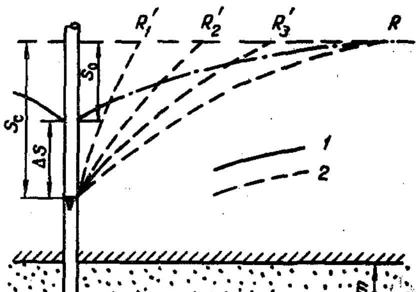

Fig. 1. Diagram illustrating the calculation of the percolation coefficient by different methods: 1) actual depression surface; 2) calculated (fictitious) depression surfaces.

In the first method the percolation coefficient is calculated from the actual depression surface of the percolation flow, and the Dupuit equations are employed [1–4]:

$$Q=\frac{2\pi k_D m(S_n-S_{n+1})}{\ln(r_{n+1}/r_n)}=$$

$$=\frac{2\pi k_D m(S_{n-1}-S_{n+2})}{\ln(r_{n+2}/r_{n-1})}=\ldots=\frac{2\pi k_D m S_0}{\ln(R/r_0)}; \quad (1)$$

$$Q=\frac{\pi k_D(h_n^2-h_{n-1}^2)}{\ln(r_n/r_{n-1})}=$$

$$=\frac{\pi k_D(h_{n+1}^2-h_{n-2}^2)}{\ln(r_{n+1}/r_{n-2})}=\ldots=\frac{\pi k_D(H^2-h_0^2)}{\ln(R/r_0)}. \quad (2)$$

If we consider the level in the perturbing and any of the observation wells (Fig. 1), Eqs. (1) and (2) take the following form:

$$Q=\frac{2\pi k_{kn} m(S_c-S_n)}{\ln(r_n/r_c)}=\frac{2\pi k_{k(n+1)} m(S_c-S_{n+1})}{\ln(r_{n+1}/r_c)}=$$

$$=\ldots=\frac{2\pi k_{kR} m S_c}{\ln(R/r_c)}; \quad (3)$$

$$Q=\frac{\pi k_{kn}(h_n^2-h_c^2)}{\ln(r_n/r_c)}=\frac{\pi k_{k(n+1)}(h_{n+1}^2-h_c^2)}{\ln(r_{n+1}/r_c)}=$$

$$=\ldots=\frac{\pi k_{kR}(H^2-h_c^2)}{\ln(R/r_c)}. \quad (4)$$

In Eqs. (3) and (4) the percolation coefficient k_{kr} (or conductivity km_{kr}) is a function of the distance r, since the flow rate is calculated from fictitious depression surfaces whose inclination is determined by the distance to the observation wells and the difference of level at the wall of the perturbing well. It is clear from Fig. 1 that as the distance between the observation wells and the perturbing well increases, the fictitious depression surfaces flatten out, always remaining steeper than the actual depression surface.

We will determine the function $k_{kr}=f(r)$. Writing (3) for two values of r, we find

Table 1

Results of Test Pumping from a Cluster of Experimental Artesian Wells*

No. of expt.	q, m^3/sec	S_r, m No. 1	No. 2	No. 3	No. 4	No. 5	$k_D m$, m^2/sec
1	2.52·10⁴	4.2	0.70	0.63	0.61	0.58	1.33·10⁵
	7.20·10⁴	11.7	2.00	1.80	1.74	1.66	
	1.08·10⁵	17.5	3.00	2.70	2.61	2.49	
	1.80·10⁵	29.2	5.00	4.50	4.35	4.15	
	2.88·10⁵	46.7	8.00	7.20	6.96	6.64	
2	3.96·10⁴	6.2	2.20	1.80	1.66	1.52	3.60·10⁴
	6.48·10⁴	10.0	3.60	2.94	2.74	2.48	
	9.72·10⁴	15.0	5.40	4.41	4.11	3.72	
	1.44·10⁵	22.0	8.00	6.54	6.10	5.52	
	3.24·10⁵	50.0	18.00	14.60	13.60	12.20	
	r, м	0.075	1.0	10.0	20.0	50.0	

* Well No. 1 is the perturbing well, wells Nos. 2-5 are the observation wells.

$$k_{kr_2}-k_{kr_1}=\frac{Q}{2\pi m}\left[\frac{\ln(r_2/r_c)}{S_c-S_{r_2}}-\frac{\ln(r_1/r_c)}{S_c-S_{r_1}}\right], \qquad (5)$$

or using Eq. (1) solved for $Q/2\pi m$,

$$k_{kr_2}-k_{kr_1}=k_D\left(\frac{S_0-S_{r_2}}{S_c-S_{r_2}}-\frac{S_0-S_{r_1}}{S_c-S_{r_1}}\right). \qquad (6)$$

At the same time, according to (1) and (3),

$$k_D=\frac{Q}{2\pi m}\,\frac{\ln(r_2/r_1)}{S_{r_1}-S_{r_2}}=$$

$$=[\ln(r_2/r_1)]\Big/\left[\frac{\ln(r_2/r_c)}{k_{kr_2}}-\frac{\ln(r_1/r_c)}{k_{kr_1}}\right]. \qquad (7)$$

From (6) and (7) we obtain

$$\alpha=(k_{kr_2}-k_{kr_1})/\ln(r_2/r_1)=$$

$$=\text{const}=f(\Delta S,\ \Delta h,\ \Delta H), \qquad (8)$$

hence

$$k_{kr}=k_{kr}^0+\alpha\ln r. \qquad (9)$$

Relation (9) is also characteristic for Eq. (4).

Examples of the determination of the percolation coefficient (conductivity) by the first and second methods are presented in Tables 1 and 2. Figure 2 shows the corresponding graphs of the function $km_{kr}=f(\ln r)$.

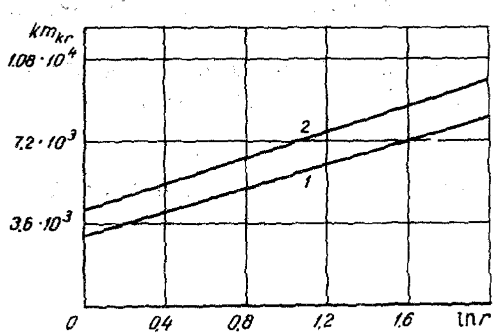

Fig. 2. Nature of the function $km_{kr}=f(\ln r)$. The graphs were plotted from the data of Table 2 (the numbers of the graphs correspond to the numbers of the experiments, km_{kr} in m^2/sec, r in m).

Considering that $S_0=S_c-\Delta S$ (Fig. 1) and using (6), from (8) we obtain

$$\alpha=c_1/[(1+c_2/\Delta S)(1+c_3/\Delta S)], \qquad (10)$$

where $c_1=Q/2\pi m$, $c_2=S_0-S_{r_1}$ and $c_3=S_0-S_{r_2}$ are constant quantities.

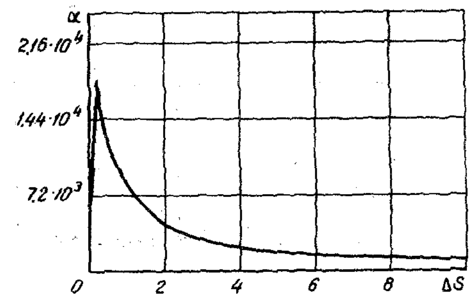

Fig. 3. Graph of the function $\alpha=f(\Delta S)$. Constructed from the data of experiment No. 1 of Table 2.

An example of the function $\alpha=f(\Delta S)$ is presented in Fig. 3.

In practice it is also necessary to consider the dependence of the percolation coefficient k_{kr} (or the conductivity km_{kr}) on the hydraulic resistance of the perturbing well (or the difference of level at its walls). We will investigate the nature of the function $k_{kr}=f(\Delta S)$.

Equating the value of the flows in (1) and (3), we obtain

$$k_{kr}=k_D/[1+\Delta S/(S_0-S_r)]. \qquad (11)$$

Graphs of the function $km_{kr}=f(\Delta S)$ are presented in Fig. 4.

Setting r = R in (11), we obtain

$$\tau=k_{kR}/k_D=S_0/S_c=q_c/q_0. \qquad (12)$$

From (12) we have

$$S_0=\tau S_c. \qquad (13)$$

Replacing S_0 in (1) and (2) with its value from (13), we obtain formulas for calculating perturbing wells for the effective value of the percolation coefficient k_D.

Thus we may conclude that k_{kr} determined by the second method depends on the hydraulic resistance of

Table 2

Results of Calculating the Conductivity of the Bed by the Second Method (from the data of Table 1)

No. of expt.	q, m^3/sec	km_{kr}, m^2/sec				α
		№ 1–2	№ 1–3	№ 1–4	№ 1–5	
1	$2.52\cdot10^4$ $7.20\cdot10^4$ $1.08\cdot10^5$ $1.80\cdot10^5$ $2.88\cdot10^5$	$3.0\cdot10^3$	$5.7\cdot10^3$	$6.5\cdot10^3$	$7.45\cdot10^3$	$2.6\cdot10^3$
2	$3.96\cdot10^4$ $6.48\cdot10^4$ $9.72\cdot10^4$ $1.44\cdot10^5$ $3.24\cdot10^5$	$4.2\cdot10^3$	$7.1\cdot10^3$	$8.0\cdot10^3$	$9.0\cdot10^3$	$2.8\cdot10^3$

the perturbing well (or the difference of level at its walls) and the distance to the observation well. Its value k_{kR} determined with allowance for the radius

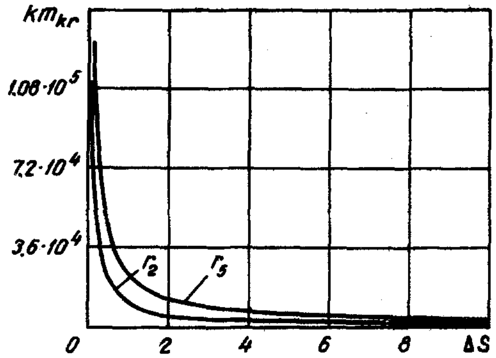

Fig. 4. Graph of the function $km_{kr} = f(\Delta S)$. Constructed from the data of experiment No. 1 of Table 1.

of influence (individual test pumpings) is usually less than the value k_D determined by the first method (from observation wells) by a factor of 2–3 or more.

It follows from (1)–(4) that in calculating ground water reserves and determining the total flow into drains (wells, mine workings, etc.) it is necessary to use the coefficient k_D. In this case the perturbing drains should be calculated with allowance for the difference of level at their walls or the well efficiency τ.

NOTATION

Q is the percolation flow rate (output of the well); k_D is the Dupuit percolation coefficient determined from Eq. (1) or (2); m is the intensity of the flow; $S_n = H - h_n$ is the reduction of the level at distance r_n from the axis of perturbing well; H is the head at the radius of influence R; $h_n = H - S_n$ is the same at the distance r_n; $S_0 = H - h_0$ is the reduction of the level at the edge of the sink, i.e., in the bed at the outer wall of the perturbing well; $S_c = H - h_c$ is the same inside the perturbing well; h_c and h_0 denote the head in the well and at its outside wall, respectively; r_c and r_0 are the inside and outside radii of well, respectively; k_{kr} is the percolation coefficient (or conductivity km_{kr}) in Eqs. (3) and (4); ΔS, Δh, ΔH are the piezometric discontinuity, seepage gap, and overhang gap; k_{kr}^0 is the value of the percolation coefficient k_{kr} (or conductivity km_{kr}) at a distance r = 1 from the axis of the perturbing well; α is the slope of the graph $k_{kr} = f(\ln r)$ with respect to the ln r axis; $q_c = Q/S_c$ is the output (specific flow) of the well; $q_0 = Q/S_0$ is the specific percolation flow; τ is the efficiency of the well.

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