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VERIFICATION OF THE VAN GENUCHTEN METHOD OF DETERMINATION OF THE HYDRAULIC CONDUCTIVITY OF PEAT SOILS

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A b s t r a c t. The knowledge of hydraulic conductivity in unsaturated zone $K(h)$ has a great theoretical and practical importance for soil water balance. The existing measurement methods of that parameter are rather complicated and time-consuming, hence the still growing interest in alternative, calculation methods.

The article presents the results of laboratory tests of hydraulic conductivity of peat soil, by Wind's dried monoliths method and their comparison with calculated values obtained by Van Genuchten's formula. The authors present also the results of numerical calculation of the capillary rise in peat soil.

K e y w o r d s: hydraulic conductivity, peat soils, Van Genuchten model, capillary rise

INTRODUCTION

Unsaturated hydraulic conductivity (K) is a soil physical parameter which is related to volumetric water content (Θ) and thus to soil water suction (h). It is required as a parameter for modelling soil water transport processes and usually used as a function of soil water suction $K(h)$.

The literature provides various methods of obtaining the $K(h)$ function [1,2,4,5]. Measurements of their values are rather complicated and time-consuming. For that reason the alternative, calculation methods appear to be interesting. The application of mathematical functions to describe the water retention curve $\theta(h)$ and the conductivity function $K(h)$ offers the possibility of search for a connection between measured points. By means of least squares fitting it is further possible to find a smooth function in spite of erroneous replications. We can gain special advantages if $\theta(h)$ and $K(h)$ are described with functions containing the same parameters. In this case it is convenient to calculate these parameters from the $\theta(h)$ relationship, which is easy to obtain, and to predict conductivities.

The effects of the $K(h)$ results on soil water transport have been checked by the example of capillary water rise from the ground water table [1,2].

Moisture lost from the soil profile is replaced by the capillary rise of water from the water table. The problem is complicated by the fact that water is evaporated from the soil and plant surfaces, usually at a greater rate than can be replaced from beneath by unsaturated flow.

DESCRIPTION OF METHOD

Measuring methods

The examined soil profiles were taken from peat meadow situated in Stawek-Stoki valley, located in Poland near Lublin city. As the effect of groundwater intake exploitation, intensive dehydration of peat soil occurred on this territory. The characteristics of the object soils are shown in Table 1.

To obtain the $K(h)$ function the following laboratory examinations were done: the Wind's [7] method for the water conductivity in unsaturated zone; the sand - box method [6] for retention properties of soil profile.

The results received from laboratory tests of 2 soil profiles, pF values and $K(h)$ functions, were used to verify the calculation method for the determination of the hydraulic conductivity. The calculation of capillary rise was the second aim of this work.

$$K(h) = K_s \frac{\{1-(\alpha h)^{n-1} [1+(\alpha h)^n]^{-m}\}^2}{[1+(\alpha h)^n]^{m/2}} \quad (2)$$

where K_s - saturated hydraulic conductivity.

The calculations of $K(h)$ function were performed using the VANGEN program [5].

Capillary water rise from the ground water table Z was calculated according to Darcy equation for steady-stage conditions:

$$Z = \int_0^h \frac{dh}{\frac{q}{K(h)} + 1} \quad (3)$$

where q - capillary flux.

Table 1. Characteristics of soils

Profile	Layer (cm)	Density (g/cm^3)	Porosity	Micropores <0.2 μm	Mesopores 0.2-30.0 μm	Macropores >30.0 μm
			(% of vol.)			
A	5 - 40	0.35	82.6	26.0	25.3	31.3
	40 - 75	0.16	91.3	19.0	47.0	25.3
B	0 - 30	0.28	84.7	28.8	33.4	22.5
	30 - 60	0.21	88.3	37.3	30.3	20.8

Calculation method

Among the many functions proposed in the literature, the relations developed by Van Genuchten [1,2,4,5] are prominent in recent references.

The empirical Van Genuchten equation [3] for the soil water retention curve reads:

$$\frac{\Theta - \Theta_r}{\Theta_s - \Theta_r} = [1 + (\alpha h)^n]^{-m} \quad (1)$$

where Θ - water content (cm^3/cm^3), Θ_s - saturated water content (cm^3/cm^3), Θ_r - residual water content (cm^3/cm^3), h - suction head (cm), n, α - parameters, determining the shape of the pF-curve, $m = 1 - \frac{1}{n}$.

The final Van Genuchten [3] analytical function describing the unsaturated hydraulic conductivity in terms of soil water pressure head is written as:

The final calculations of capillary rise were performed using the PODSIĄK program [8].

RESULTS AND DISCUSSION

The results of laboratory investigations and numerical calculations are shown in Figs 1-3. Figure 1 shows the pF values obtained from laboratory measurement of examined soil profiles. Because it was not necessary for the Van Genuchten model, the approximation of obtained measuring points was not done. Lines presented in Fig. 1 are only proposition, without statistical support.

The results of $K(h)$ functions calculation, based on values presented in Fig. 1 are shown in Figs 2 and 3. Parameters of the Van Genuchten model obtained as the effect of the calculations are presented in Table 2.

The measured values presented in Fig. 2 were approximated by a function of the following type: $K(h) = A \cdot h^B$. Obtained correlation coefficients

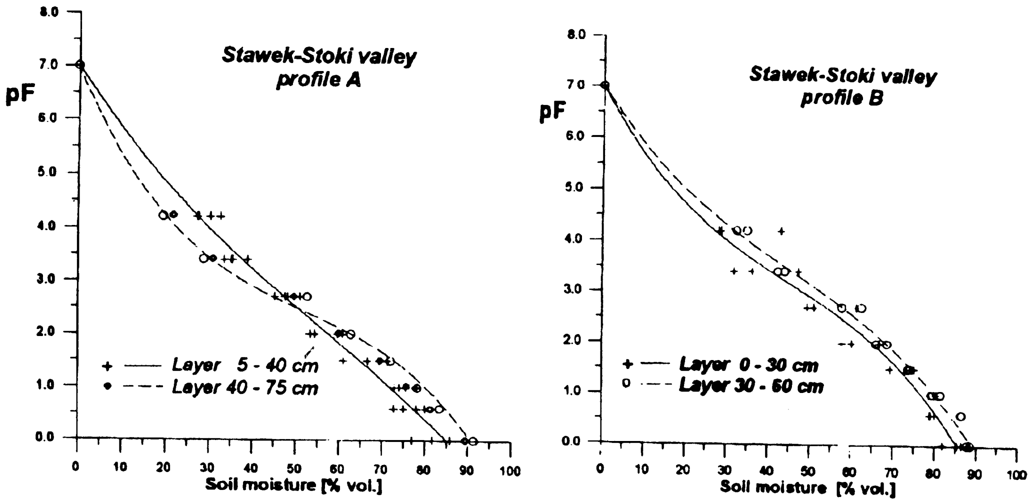

Fig.1. The pF measured values for examined soil profiles A and B.

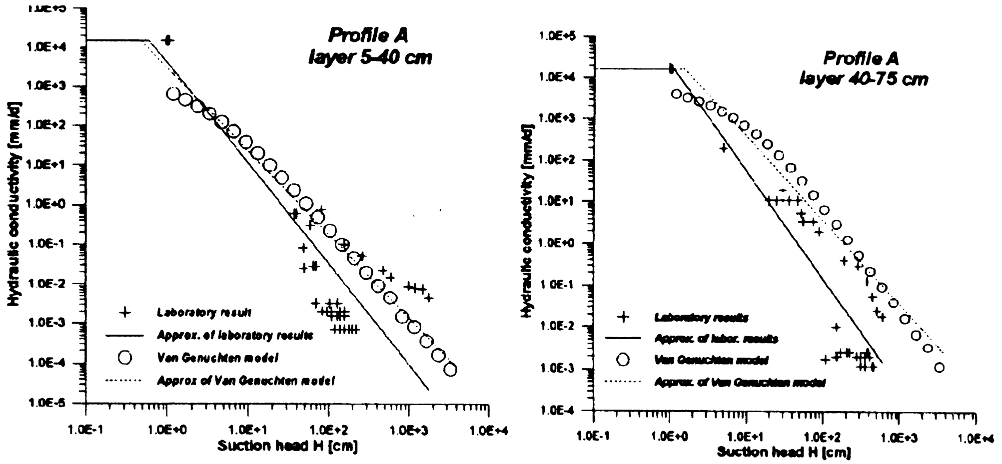

Fig. 2. Measured (+) and calculated (o) hydraulic conductivity for profile A, layer 5-40 cm (left) and 40-75 cm (right).

include: 0.837 and 0.910 for profile A, and 0.734 and 0.886 for profile B.

Figures 2 and 3 show also the comparison of $K(h)$ values received from laboratory measurement and numerical calculation. Basing on those comparisons it can be said that Van Genuchten model doesn't give a good approximation of $K(h)$ values. Looking for better connections between calculated and measured data, the authors decided to perform the approximation of data obtained from Van Genuchten formula by the function of the same, as measured one type. After that operation the correlation between both, numerical and measured, obtained functions appears to be little better, but still not good enough. It seems that continuation of calculation method of $K(h)$ function research, for peat soils is very necessary. The approximation method of obtained values has also a great importance.

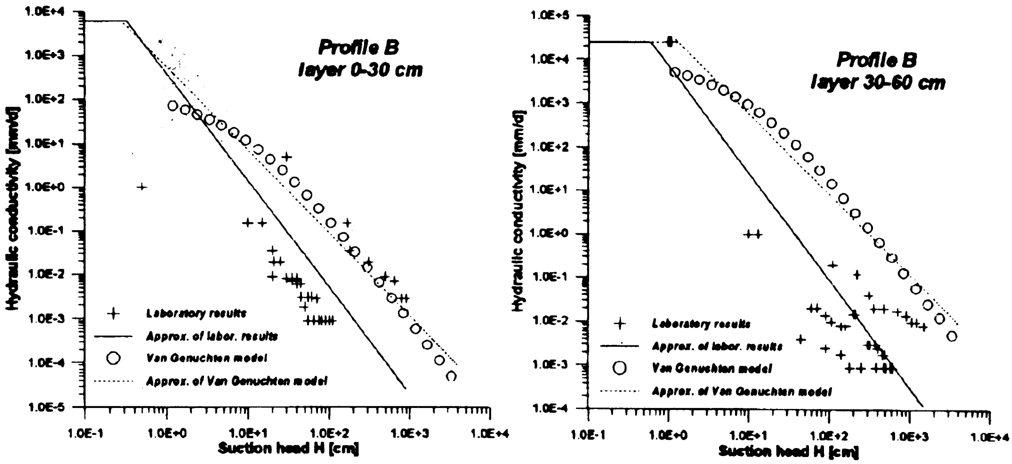

Fig. 3. Measured (+) and calculated (o) hydraulic conductivity for profile B, layer 0-30 cm (left) and 30-60 cm (right).

T a b l e 2. Parameters of the Van Genuchten model

Profile	Layer (cm)	Θ_r (% of vol.)	α	n
A	5 - 40	1.0	0.1775	1.1339
	40 - 75	1.0	0.0523	1.2183
B	0 - 30	1.0	0.0518	1.1476
	30 - 60	1.0	0.0445	1.1406

Figure 4 presents the results of computer simulation of capillary water rise for soil profile B. The assumed water level lays 60 cm under the ground surface. In simulations were used the water conductivity values obtained from laboratory measurement and Van Genuchten relation. Water losses for transpiration have values from 0.0 to 10.0 mm/d. The differences between water rise calculated for the same profiles are clearly visible. Of course

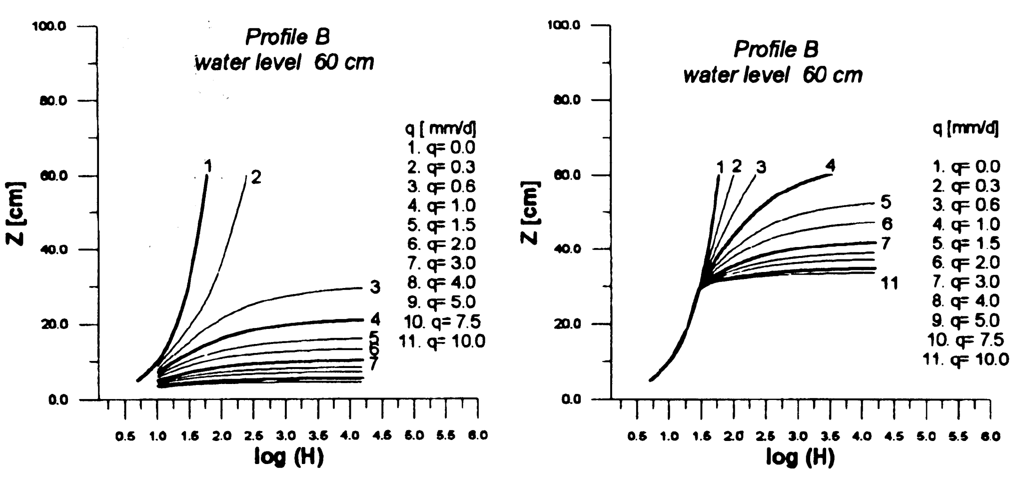

Fig. 4. Relation between height of capillary rise (Z) and soil water suction (h) for the different capillary flux (q) under stady state conditions. Left - using measured $K(h)$ function. Right - using calculated (Van Genuchten) $K(h)$ function.

there is only one profile, without the laboratory measurement of water rise possibilities, but presented simulation shows the importance of good estimation of $K(h)$ function. It is impossible to say anything about the quality of obtained simulation results without laboratory verification, but it is visible that even small differences in objective $K(h)$ function can case great deviation in numerical simulations which use it as the main parameter.

CONCLUSIONS

1. Presented comparison of laboratory measurement and Van Genuchten relation for $K(h)$ determination indicates the necessity of continuation of the research providing to obtain a better calculation method for peat soils. The results of that comparison show that in Stawek-Stoki valley conditions the Van Genuchten's relation doesn't give a good enough approximation for peat soils.

2. Method of approximation of values calculated from Van Genuchten relation by $K(h) = Ah^B$ type function, used by the authors, gives only a little better approach to measured values.

3. The simulation of water capillary rise, performed using the $K(h)$ function obtained from measured and calculation method, shows the importance of good estimation of that parameter. So great an influence of $K(h)$ parameter on quality of obtained simulation results indicates also the importance of approximation function used. The postulated earlier research continuation must be also interesting in that aspect of the problem.

4. The water capillary rise properties of peat soils, presented in this paper, are rather weak, but there is still too few laboratory's observations to have the reliability of simulation. The first step of the solution of that problem is obtaining the good $K(h)$ relation.

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