Estimation of hydraulic parameters of Campbell model

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1. Introduction

Relation among saturation, suction head and hydraulic conductivity should be estimated for the analysis of unsaturated flow. Watanabe[1] and Abozeid Gamal[2] have proposed two back analytical techniques for the estimation of those relations on the basis of Van-Genuchten and Campbell models respectively. Parameters in the Van-Genuchten model are essentially estimated from the saturation distribution in a column sample. On the other hand, Campbell parameters can be estimated from the data of evaporation change. Those relations drawn by these parameters independently estimated by two techniques have been compared in this study by using Toyoura standard soil.

2. Scope of this study

Van-Genuchten parameters of Toyoura standard soil have been already reported by Abozeid Gamal[2]. The determined parameters for Toyoura sand are listed in Table 1. So that the main purpose of this study was focused on the estimation of Campbell model parameters. The shapes of these models are quite different to each other as shown in Figure 1. It is very difficult to estimate parameters in Campbell model by simple curve fitting to Van-Genuchten model. Therefore, estimation by experiments is needed.

Van-Genuchten model

$$S_e = \frac{S - S_{\min}}{S_{\max} - S_{\min}} (0 \le S_e \le 1)$$

$$S_e = \left\{1 + \alpha |\psi|^n\right\}^{-m} (\alpha > 0)$$

$$n = \frac{1}{1-m} (0 < m < 1, n > 1)$$

$$k = S_e^{1/2} \left\{1 - (1 - S_e^{1/m})^m\right\}^2$$

Campbell model

$$\theta = \theta_{sat} \left(\frac{\psi_e}{\psi}\right)^{1/b}$$

$$k = k_{sat} \left(\frac{\theta}{\theta_{sat}}\right)^m$$

θ_r	0.0045 m^3/m^3
θ_s	0.4428 m^3/m^3
α	2.642 m^{-1}
m	0.89654

Table 1. Van Genuchten parameters of Toyoura soil

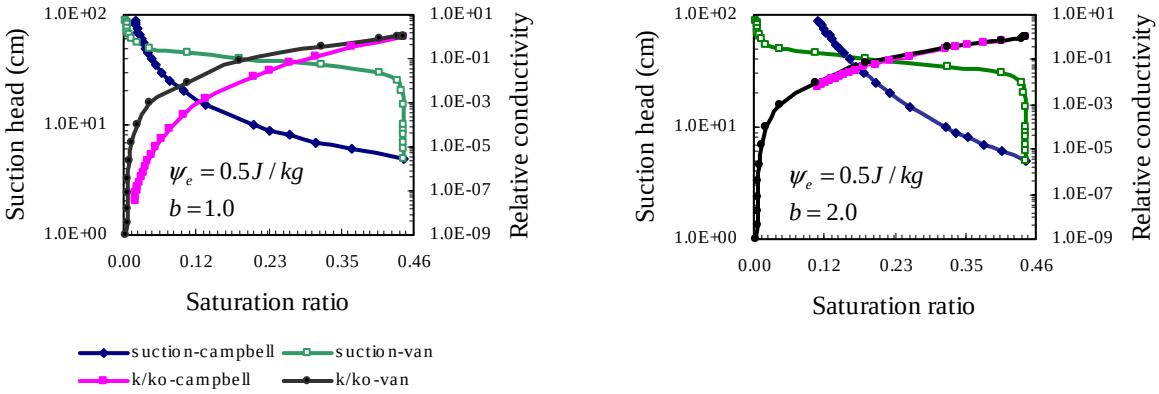

Fig. 1 Difference between Campbell model and Van-Genuchten model

3. Experimental Work

The evaporation experiments were carried out in a controlled temperature and relative humidity chamber for measuring evaporation change to determine Campbell parameters. Toyoura standard soil has been used as a sample. The sample has a volumetric water content of 0.445 cm^3/cm^3. It has a dry density of 1.46(10^3) kg m^{-3} and a saturated hydraulic conductivity of 0.0203 kg s m^{-3} (0.02 cm/sec). The dimensions of the used sample are LxWxH: 220X159x30 mm. One-dimensional flow due to evaporation was created by sealing sidewalls and bottom of the sample. The experiments were carried out under an air temperature of 35°C and a relative humidity of 40 %. At the beginning of experiment the sample was fully saturated. During the experiments, the sample was placed inside the chamber on the plate of a balance connected with a data logger (Fig. 2) due to the measurement of evaporation rate. Weight of the sample was recorded periodically in order to determine the evaporation water loss with time. The evaporation experiments were stopped when the sample weight remained constant with time.

Key words: a controlled temperature and relative humidity chamber, evaporation measurement
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4. Estimation of Campbell model parameters

Because this approach deals with an evaporation experiment, hydrodynamic properties of a drying process are estimated. Many calculations with changing the hydraulic properties of the Toyoura soil were performed to minimize the sum of the squared differences between the measured and simulated evaporation rate during 50 hours of the experiment. Figure 3 schematically shows the procedure of the used back analysis technique to estimate the Campbell model parameters.

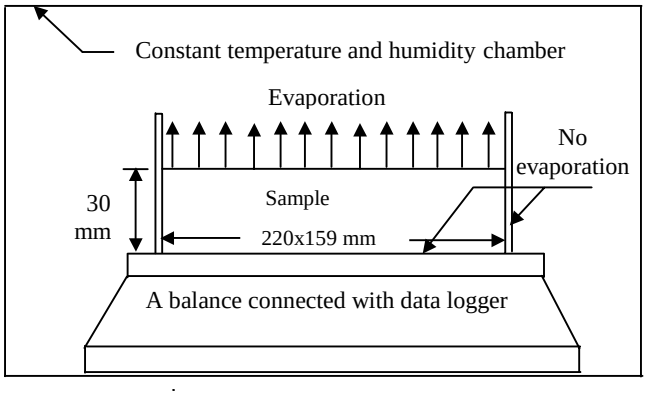


Fig. 2 Apparatus used for evaporation experiment

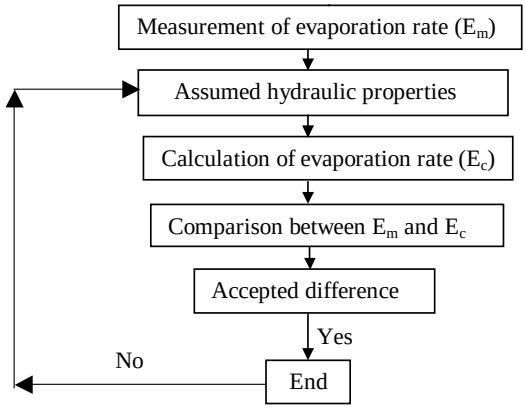
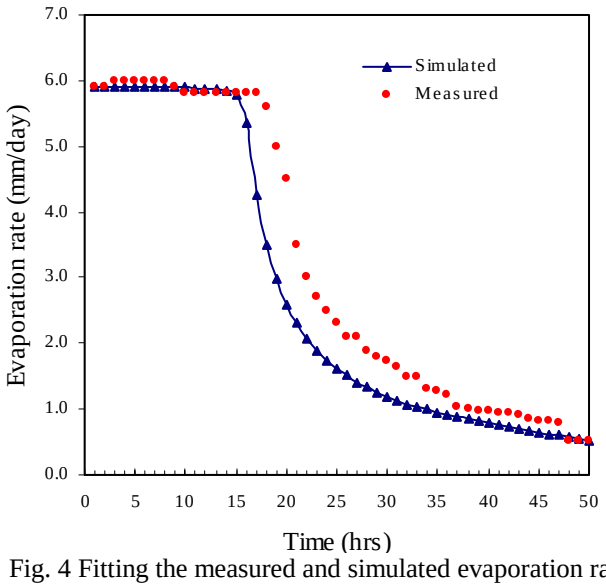


Fig. 3 Procedure of back analysis technique

5. Obtained results from the experiment and comparison with Van-Genuchten model

The fitted parameters for the used Toyoura standard soil was found to be, the soil parameter, b = 5.4 and air entry value, ψ_e = -1.1 J kg^{-1}. The values of b and ψ_e locate in the range for typical soils, expected by Campbell[4]. Figure 4 shows a comparison between the measured and simulated evaporation, during the time of experiment. As shown in this figure, the results are in good agreement. Figure 5 displays the relations among saturation, suction head and hydraulic conductivity. Van-Genuchten model used by parameters shown in Table 1 is also presented. From this figure, the water retention curves obtained from Campbell and Van model agreed with each other from saturation to 65 % saturation.



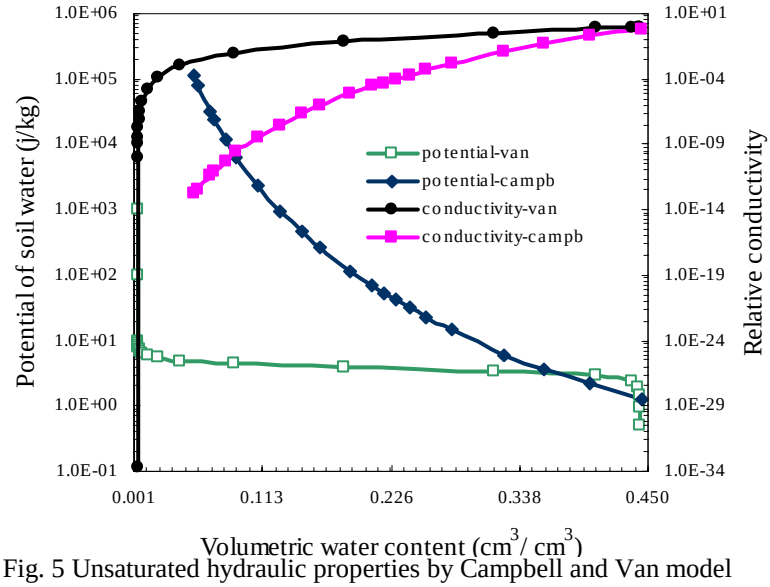


Fig. 4 Fitting the measured and simulated evaporation rate. Fig. 5 Unsaturated hydraulic properties by Campbell and Van model

5. Conclusions and recommendation

This study proposed a simple technique for estimating the Campbell model parameters as well as the unsaturated hydraulic properties. This study needs only simple data of evaporation change. In this study, we can conclude that the estimated Campbell model parameters can be successfully used to analyze the transient change of the evaporation rate from a soil sample under defined atmospheric condition. Advantage of Campbell model is easy to measure and it is fit for the field test since evaporation change can be observed by 2-sensor type evaporation meter [3]. Therefore, the applicability of the proposed study for the actual field condition is recommended for further research work.

Reference

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