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Determination of Relative Hydraulic Conductivity from Moisture Retention Data Obtained in the Bandelier Tuff

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DETERMINATION OF RELATIVE HYDRAULIC CONDUCTIVITY FROM MOISTURE RETENTION DATA OBTAINED IN THE BANDELIER TUFF

by

W. V. Abeele

ABSTRACT

A method for calculating unsaturated hydraulic conductivity from measured values of matric potential and saturation ratio is applied to data for the Bandelier tuff. A method described by Campbell requires that the measured data satisfy a particular log-log relationship. The coefficient of correlation using the predictive formula in actual measurements is highly significant at matric potentials lower than -10 kPa (-0.1 bar). The decrease of the relative hydraulic conductivity with decreasing saturation ratio is more rapid for crushed tuff than undisturbed tuff.

I. INTRODUCTION

Several methods have been suggested to calculate unsaturated hydraulic conductivities as a function of water content. Green and Corey[1] compared the results of such methods with measured values. Some modifications to the methods were suggested subsequently by Jackson[2] to obtain better agreement between calculated and measured values.

II. METHODS

Campbell[3] described a method for calculating unsaturated hydraulic conductivity that depends upon the functional relationship between matric potential and relative water content. The empirical expression employed by Campbell is given in Eq. (1).

$$\psi = \psi_e \left(\frac{\theta}{\theta_s}\right)^{-b} \quad , \qquad (1)$$

where ψ is the matric potential,
θ is the moisture content,
ψ_e is the air entry matric potential,
θ_s is the saturated moisture content, and
b is a constant for a given soil.

$$\ln \psi = \ln \psi_e - b \cdot \ln \left(\frac{\theta}{\theta_s}\right) \quad , \qquad (2)$$

where $\ln \psi_e$ is a constant for a given soil.

Equation (2) requires that a log-log plot of relative water content vs matric potential be a straight line, with slope equal to -b. Jackson[2] presents evidence that such a relationship can be used to compute hydraulic conductivity as a function of moisture content using Eq. (3).

$$\frac{K}{K_s} = \left(\frac{\theta}{\theta_s}\right)^{2b+3} \quad , \qquad (3)$$

where K is the hydraulic conductivity and K_s, the saturated hydraulic conductivity. Empirical equations similar to Eq. (3) have been used by Hillel and Gardner.[4]

III. RESULTS

The above methods were used to calculate hydraulic conductivity functions for Bandelier tuff at a radioactive waste disposal site at the Los Alamos Scientific Laboratory (LASL). Moisture characteristic data for both solid and crushed tuff were tested for linearity, as expressed in Eq. (2), with data provided by Merle Wheeler from LASL. The coefficient of correlation r between ψ and θ in the observed data was calculated. As predicted by Campbell[3] departures from a straight line occurred at potentials >-10 kPa (-0.1 bar). However, for potentials <-10 kPa, r was found to be 0.995 for both solid and crushed tuff when the moisture characteristic was measured with pressure extraction techniques, and 0.999 in crushed tuff when the moisture characteristic was determined with thermocouple psychrometers. The linearity for measurements of matric potential vs relative moisture content is displayed in Fig. 1.

Values for b and 2b + 3 for solid and crushed tuff, measured with pressure plates or a psychrometer, are given in Table I. It should be kept in mind that

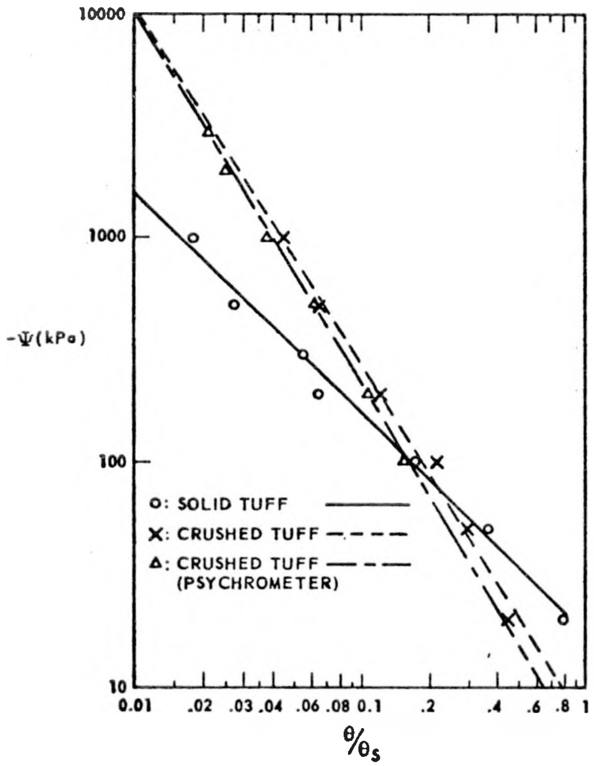

Fig. 1
Matric potential curves for Bandelier tuff used to determine b-values.

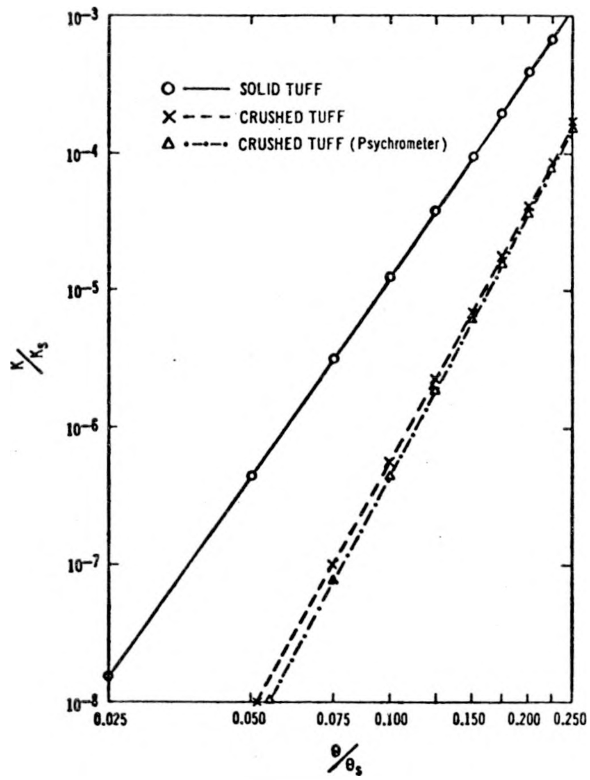

Fig. 2
Relative hydraulic conductivity as a function of degree of saturation.

the higher the values for 2b+3, the more rapid the decrease of the relative hydraulic conductivity K/K_s will be with decrease in relative moisture content θ/θ_s. Figure 2 shows how the relative hydraulic conductivity varies in function of changing relative moisture content in the three cases under study. The steeper slopes obtained for crushed tuff clearly indicate a more rapid decrease of the relative hydraulic conductivity K/K_s with decreasing saturation ratio.

TABLE I

CONSTANTS USED IN PREDICTING K/K_s

Type of Tuff	Method Used	b	2b + 3
Solid	Pressure Plates	0.94230	4.88460
Crushed	Pressure Plates	1.61421	6.22842
Crushed	Psychrometer	1.65965	6.31930

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