The $\theta(\psi)$–function of waste rock: measurements and pedotransfer functions

Uwe Hoepfner [1], Murray D. Fredlund [2]

1. Introduction

The determination of the $\theta(\psi)$–function is laborious and costly. For applications like water balance studies these functions are often predicted with pedotransfer functions (PTF) with the help of soil characteristics like grain size or density, which are easy to measure. A first approach to predict the $\theta(\psi)$–function was the physically based method of ARYA and PARIS (1981). ARYA predicts the pore radius and pore volume from a grain size distribution, and then converts the pore volume and radii to water content and tension. A second class of PTFs are regression based methods that depend on clay content or soil density (e.g. RAWLS a. BRAKENSIEK, VEREECKEN).

The FREDLUND and WILSON estimation method (1997) is based on the physico–empirical method and estimates the $\theta(\psi)$–function from the grain–size distribution curve and volume–mass properties. The grain–size distribution is divided into small groups of uniformly–sized particles. A packing porosity and $\theta(\psi)$–function is assumed for each group of particles. The incremental $\theta(\psi)$–functions are then summed to produce a final curve.

These PTFs are extensively tested on natural soils, but rarely on anthropogenic soils or materials like waste rock or tailings. HOEPFNER et al. (2003) has shown that a calibrated FREDLUND a. WILSON–PTF could be successfully applied to anthropogenic cover soils.

Field tests of cover systems for remediation of contaminated mining sites in East Germany has shown that the underlaying waste rock takes part in the water balance of the cover system. Deep drying in summer seasons results in capillary rise of water from waste rock to the overburden cover soil. Therefore the hydraulic characteristics of the waste rock are important for the assessment of the performance of cover systems as well as predicting the water balance and water quality of top soils. The $\theta(\psi)$–function of waste rock was therefore studied.

Fig. 1: (a) Cover soil and waste rock (b) Typical stony waste rock material. Field test plots Ronneburg Site

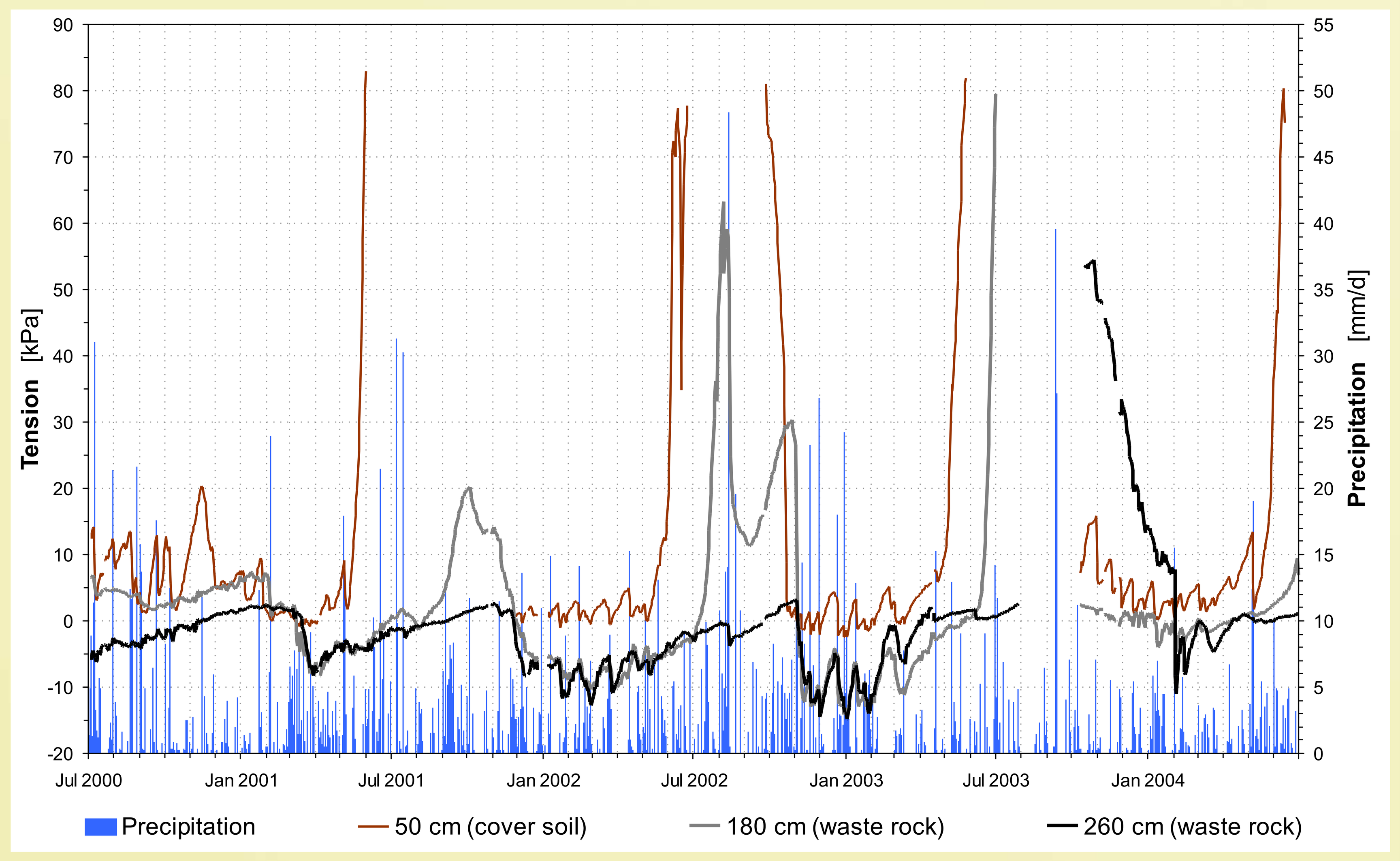

Fig. 2: Tension in cover soil (1,6 m) and waste rock. Field test plots Ronneburg Site

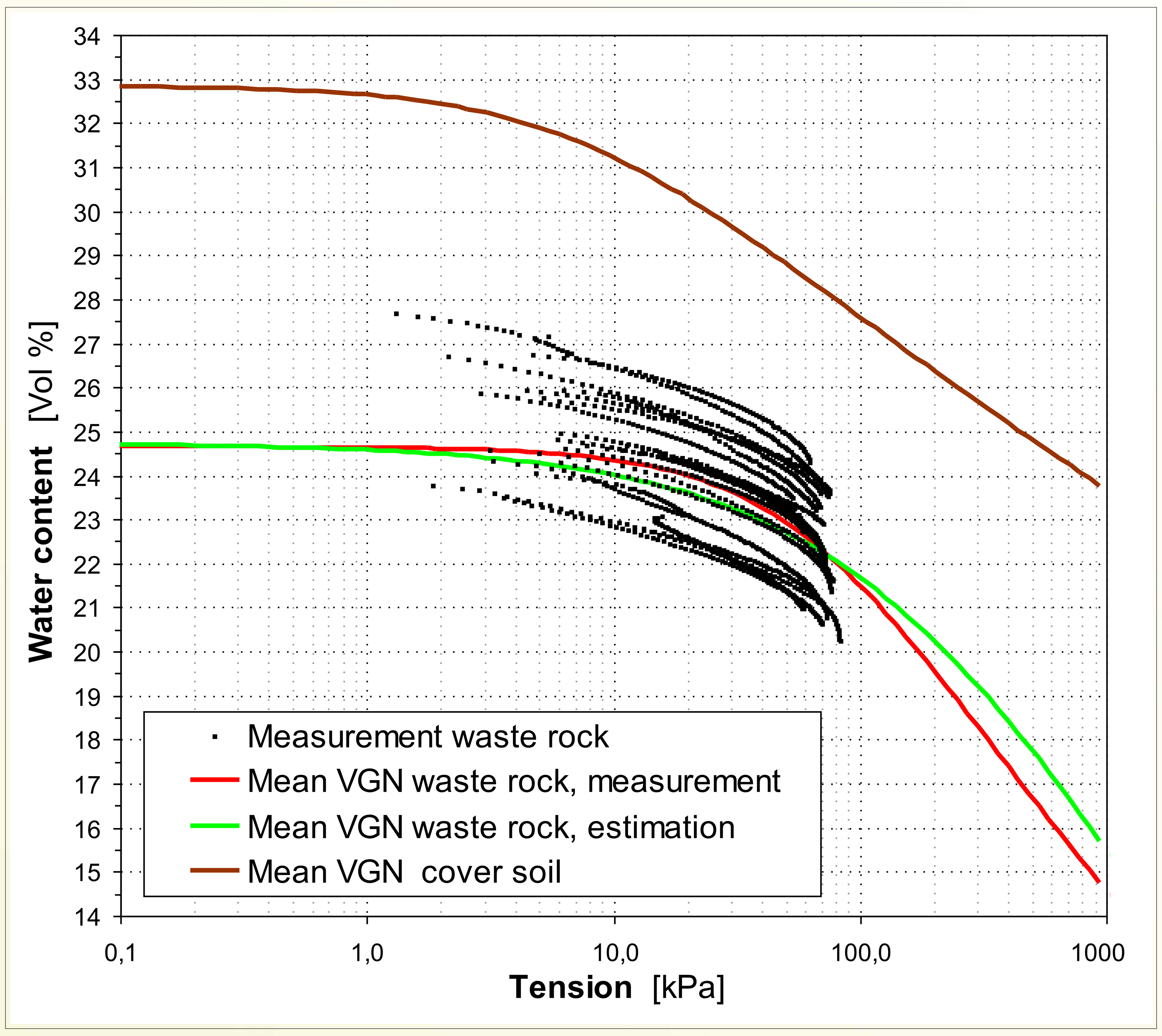

Fig. 3: Measurements of $\theta(\psi)$–functions, waste rock material, and prediction of mean $\theta(\psi)$–function, calibrated FREDLUND and WILSON–PTF

2. Methods

We measured the $\theta(\psi)$–function with the evaporation method (20 samples of waste rock, 250 cm^3). The waste rock material from the dumps of the Ronneburg Uranium Mining Site is a mixture of fine material (11 % clay, 37 % silt, 54 % sand) with a high stone content (37 %). Because this waste rock is relocated in a open pit with heavy dumpers, we condensed the samples up to 1,9–2,1 g cm^{-3}.

We tested the PTFs of RAWLS a. BRAKENSIEK, VEREECKEN, ARYA a. PARIS 1981 and FREDLUND a. WILSON with the software SOILVISION. The $\theta(\psi)$–functions are parameterized with the VAN GENUCHTEN (VGN) approach.

3. Results

The prediction of the $\theta(\psi)$–function with the regression based methods was not possible for the stony waste rock material. The tested methods of RAWLS a. BRAKENSIEK and VEREECKEN shows high deviation to the measured curves, as expected. Also, the physical based method of ARYA a. PARIS didn't work well.

The results of the PTF of FREDLUND a. WILSON differs for the 20 samples, depending on the packing porosity of the sample. We increased the packing porosity an average of +12,3 % compared with the neural net prediction of SoilVision. For the cover soils of the Ronneburg site the packing porosity was increased an average of +10 % (HOEPFNER et al. 2003). Previous comparisons to soils calibrated for a site in Montana have indicated a recommended increase in the packing porosity of +27,9 % (FREDLUND 2000). With that calibration, the mean FREDLUND a. WILSON–PTF fit well the mean measured $\theta(\psi)$–function (Fig. 3), with a somewhat lower α.

Common pedotransfer functions should not be used for anthropogenic soils or materials like waste rock or tailings. High deviations of the packing porosity, the stone content and continuity and tortuosity of the pore space limit the application of this methods. For practical applications e.g. covering waste rock with top soil at mining sites, the FREDLUND and WILSON–approach gives good results. Future work could include these types of materials in the neural net prediction of SoilVision.

FREDLUND, M.; WILSON, G. a. FREDLUND, D. [1997]: Prediction of the soil–water characteristic curve from grain–size distribution curve. *3rd. Symp. on unsaturated soils. Proc., Rio de Janeiro, Brazil, 20.4-22.4.97, S. 13-23.*

FREDLUND, M. [2000]: The role of unsaturated soil property functions in the practice of unsaturated soil mechanics. *Ph.D. Thesis, University of Saskatchewan, Saskatoon, SK, Canada*

HOEPFNER, U.; WEISS, K. a. ZEPP, H. [2003]: Zur Vorhersage der $\theta(\psi)$–Beziehung von künstlichen Rohböden mittels Pedotransferfunktionen. *Mitt. Dtsch. Bodenkundl. Gesellsch., Vol. 102, S. 83-84.*

[1] Wismut GmbH, Chemnitz; *u.hoepfner@wismut.de*

[2] SoilVision Systems Ltd., Saskatoon, Canada; *murray@soilvision.com*