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Introducing Some PTF for Soil Physical Properties in Bank of Yangtze River, Nanjing District

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ABSTRACT

Pedotransfer function (PTF) is a new technique for predication of the soil physical properties (SPP). Generally, SPP such as dry density, porosity, void ratio, soil hydraulic conductivity are estimated by a semi-empirical equation. The objective of this research was developing some PTF for estimation of SPP in bank of the Yangtze River, in Nanjing city, Jiangsu province, China. The SPP that has been considered in this research were: wet density (ρ_w), dry density (ρ_d), void ratio (e), liquid limit (L_L) and plastic limit (L_P). All soil analysis carried out by the soil geotechnical analysis standard method. 650 series of data were used for calibration and more than 100 series data for verification. The result shows that most of SPP in the study area can be significantly estimated by wet density (ρ_w). For instant $\rho_{d\,=}$ 1.474 + 1.531 × ρ_w and L_1= 142.766- 54.898 × ρ_w. Base on the results a computer program has been developed to estimate the SPP.

Keywords: Soil properties, Pedotransfer function, Yangtze River, Nanjing

INTRODUCTION

A large number of methods currently exist to determine soil physical properties (SPP) in situ field or laboratory. In spite of the fact that measurements provide the most exact determination of soil physical properties, they often require a substantial investment in both time and money. Moreover, many vadose zone studies are concerned with large areas of land that may show substantial spatial variability in the soil hydraulic properties. It is theoretically impossible to approach the meaningful measurements in such studies, thus it is indeed essential to find an inexpensive and rapid methods to determine soil hydraulic properties. (Schaap *et al*., 2001).

Many indirect methods for determining soil physical properties have been developed. Most of these methods can be classified as pedotransfer functions (PTF) because they convert existing surrogate

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data (e.g. particle-size distributions, bulk density and organic matter content) into soil physical data. All PTFs have a strong degree of empiricism that they contain model parameters which were calibrated on existing soil physical databases. A PTF can be as simple as a lookup table that gives physical parameters based to textural class or include linear or nonlinear regression equations. PTFs with a more physical foundation exist, such as the pore-size distribution models by Burdine (1953) and Mualem (1976), which offer a method to calculate unsaturated hydraulic conductivity from water retention data. Models by Haverkamp and Parlange (1986) and Arya and Paris (1981) use the shape similarity between the particle and pore-size distributions to estimate water retention. Tyler and Wheatcraft (1989) combined the Arya model with fractals mathematics, while Arya recently extended the similarity approach to estimate water retention and unsaturated hydraulic conductivity.

Since PTFs are often developed empirically, their applicability may be limited to the dataset which is used to define the method (Donatelli *et al*., 1996 ; Wosten *et al.*, 1999). Neural network analysis has also been used to establish empirical PTFs (Pachepsky *et al.*, 1996; Schaap and Leij, 1998; Schaap *et al.*, 1998; Minasny and McBratney, 2002). An advantage of neural networks over traditional PTFs is that they do not require a priori model concept. The optimal and possibly nonlinear relations that link input data (particle size data and bulk density, etc.) to output data (liquid limit, hydraulic parameters, etc) are obtained and implemented in an iterative calibration procedure. As a result, neural network models typically extract the maximum amount of information from the data (Schaap *et al*., 2001). Rosetta uses a neural network for prediction and the bootstrap approach to perform uncertainty analysis SOILPAR2 can compute estimates of soil hydrological parameters by several procedures, and compares the estimates with measured data using statistical indices and graphs (Givi *et al.*, 2004).

The objective of this paper is to develop several pedotransfer functions in estimating some soil physical properties in the natural soils in the bank of Yangtze River in Nanjing city, Jiangsu province, China.

MATERIALS AND METHODS

MATERIALS

The base material of this research is soil geotechnical analysis that collected from the library of Nanjing Hydraulic Research Institute (NHRI) and department of structure and water resource of Hohahi University, Nanjing, P. R. China. The soil samples were selected from different depths of the natural soil in bank of Yangtze River at Jiangsu province, Nanjing city, China at June 2005. The total number of data was 750 series. The computitonal processes were done with computer software such as spreadsheet (Excel) and statistical software (Curve expert, SPSS).

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Figure 1. Soil sampling location in the eastern part of China

METHODS

The soil physical properties consist of wet density (γ_w), dry density (γ_d), void ratio (e), porosity (n), elastic limit (El), plastic limit (PL) and plasticity index (PI). All soil analysis carried out by the soil geotechnical standard methods. Six hundred and fifty series of data were used for calibration and the others (100 series) were used for verification. The process which used for data analysis and driving PTF was as follow: at the beginning of data analysis and driving PTF two parameters were selected (for example γ_w and γ_d), then the data was classified and the subsequent stage is driving PTF by curve expert from the 650 series, after that, analysis of variance (ANOVA) for PTF by SPSS was performed. The next step was Predication of target parameter by the 100 remaining data points and PTF. Last step was paired difference sample analysis of observed and predicted data.

Two statistical analyses has been used for analyzing data. The first was analysis of variance for estimation of a liner or nonlinear equation. The second one was analysis of variance for definition of difference between the predicted parameter through the equation and observed data.

RESULT AND DISCUSSION

As the wet density is the first parameter and more popular than the other parameters that is measured in soil geotechnical analysis, so it was tried to estimate another parameter base on wet density.

Dry density

The analysis has been run on dry density also the process took 650 series data for calibration process. Figure 2 shows the dry density *vs* wet density for the calibration data as well as residual for the data.

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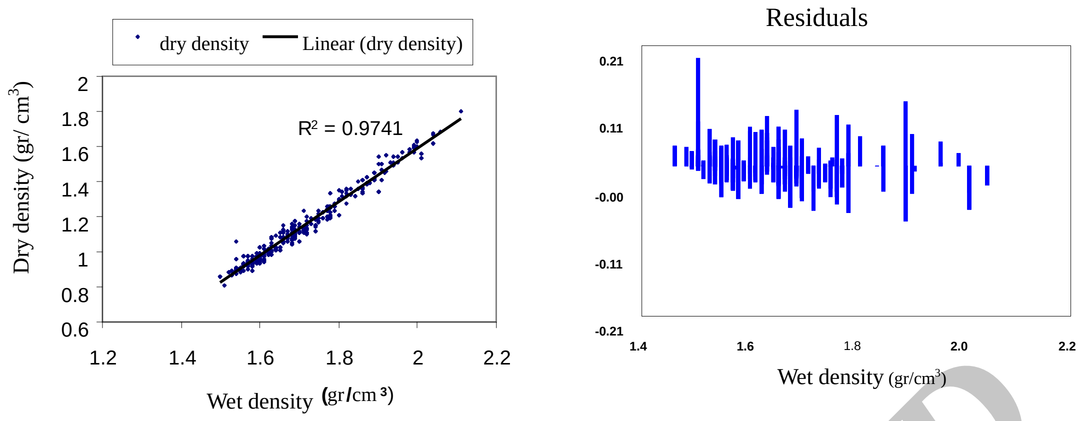

Figure 2. The relationship of wet *vs* dry density (left) and residual of PTF (right)

The result shows a PTF for the dry density, as equation 1. It shows that the correlation coefficient between ρ_d and ρ_w is more than 0.98.

$$\rho_d = 1.474 - 1.531 \times \rho_w \qquad \text{(Equation 1)}$$

Analysis of variance (ANOVA) is done for the dry density data. It is shown in Table 1. One hundred series data were used for the verification. The extracted model for predication of ρ_d, was verified with verification data. The result of the verification is presented in Figure 3.

The results of paired sample difference analysis (PSDA) test was done by the SPSS software is shown in Table 1. The average squared error (ASE) of the estimate is 0.001. It means that the PTF could estimate the dry density with a high accuracy. The result shows that the standard deviation between the observed and predicated data is less than 0.03 which confirms the last result.

Void ratio

The result shows the following equation for estimation of void ratio base on wet density.

$$e = \frac{1}{4.504 - 6.105 \times \rho_w + 2.275 \times \rho_w^2} \qquad \text{(Equation 2)}$$

Figure 4 shows the void ratio *vs* wet density for the calibration data as well as residual of regressed data.

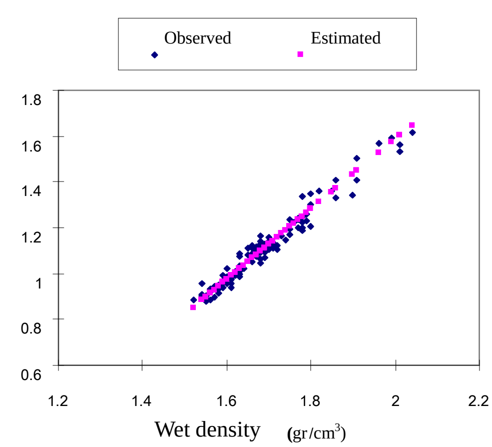

Figure 3. Comparison of the observed and estimated dry density for the verification data

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Table 1. Analysis of variance for dry density estimation

	Sum of squares	df	Mean square	F	Sig.
Regression	3.107	1	3.107	3202.630	.000
Residual	.119	123	.001		
Total	3.227	124			

Table 2. Paired samples differences test (PSDT)

Paired differences					T	df	Sig. (2-tailed)
Mean	Std. deviation	Std. Error mean	95% Confidence interval of the difference				
			Lower	Upper			
-0014	.03175	.00284	-.00576	.00548	-.049	124	.961

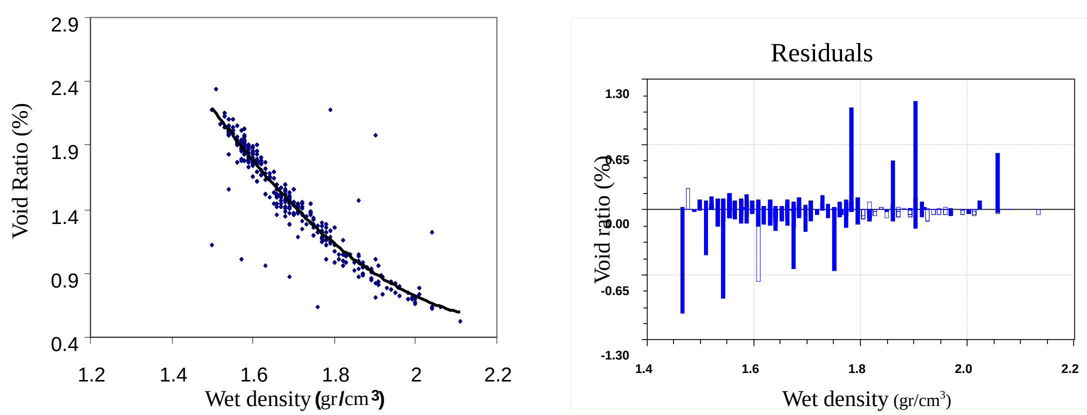

Figure 4. The relationship of wet density vs. void ratio (left) and residual of PTF (right)

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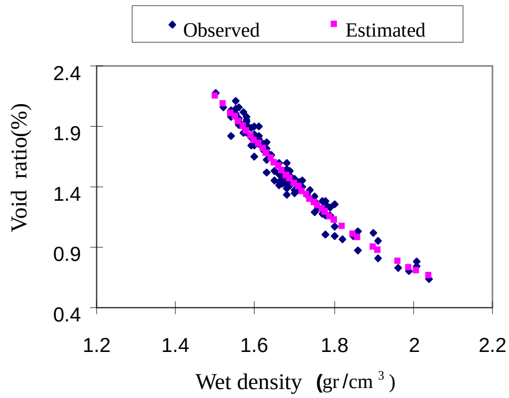

Figure 5. Comparison of the observed and estimated data for the void ratio

The average squared error (ASE) of the estimate is 0.005. It means that the PTF could estimate the void ratio with a high accuracy. The result of the verification is presented in Figure 5.

Liquid limit

The similar procedure was carried out for liquid limit (L_L). Fig 6 shows the liquid limit in comparing with wet density. The estimation of L_L based on PTF is as equation 3.

$$L_l = 142.766 - 54.898 \times \rho_w \quad \text{(Equation 3)}$$

The R squared and standard error for the calibration data were 0.77 and 5.33, respectively. It can be concluded that the PTF would have low accuracy. So it was expectable that the ASE for estimation process was relatively high (22.63) for the verification data. The result shows that the PTF has low but acceptable accuracy for estimation of L_L.

It was tried to find a more accurate PTF with other parameters (eg. Dry density, void ratio) but it was not founded.

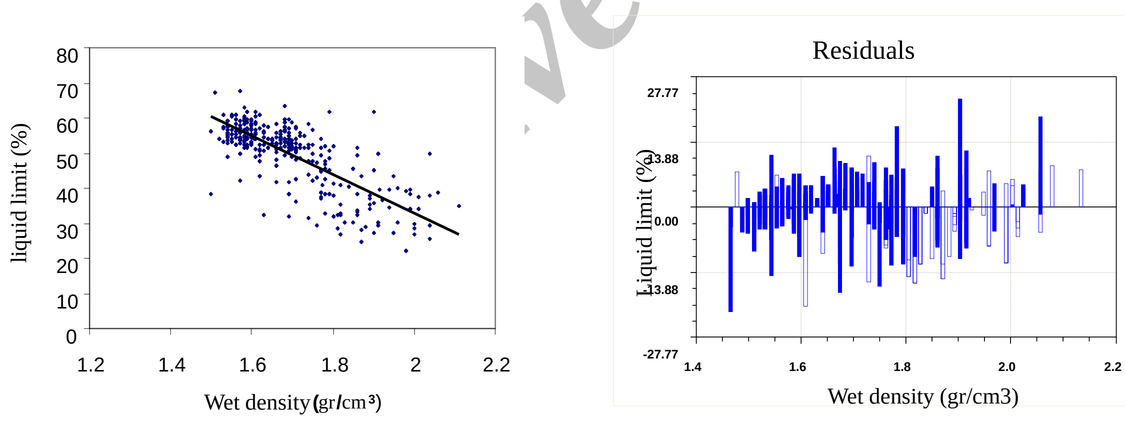

Figure 6.The relationship of wet density *vs* liquid limit (left) and residual of PTF (right)

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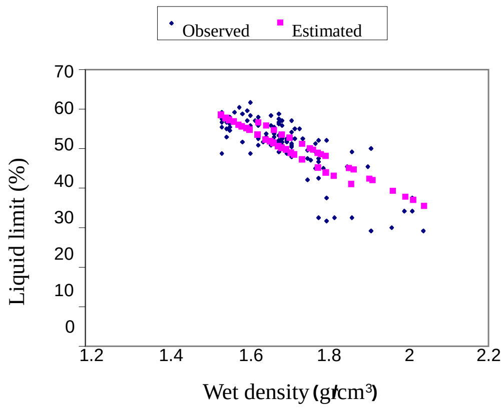

Figure 7. Comparison of the observed and estimated data for the Liquid limit

Plastic limit

The same procedure has been executed for Plastic limit (P_L). The result shows that no acceptable PTF can be found for P_L in compare with wet density. So it was tried to find a PTF with other parameters. The result shows that it can find a meaningful PTF on P_L and L_L. Figure 8 shows the P_L in compare with L_L. It shows that R squared of 0.90 and standard error of 1.73.

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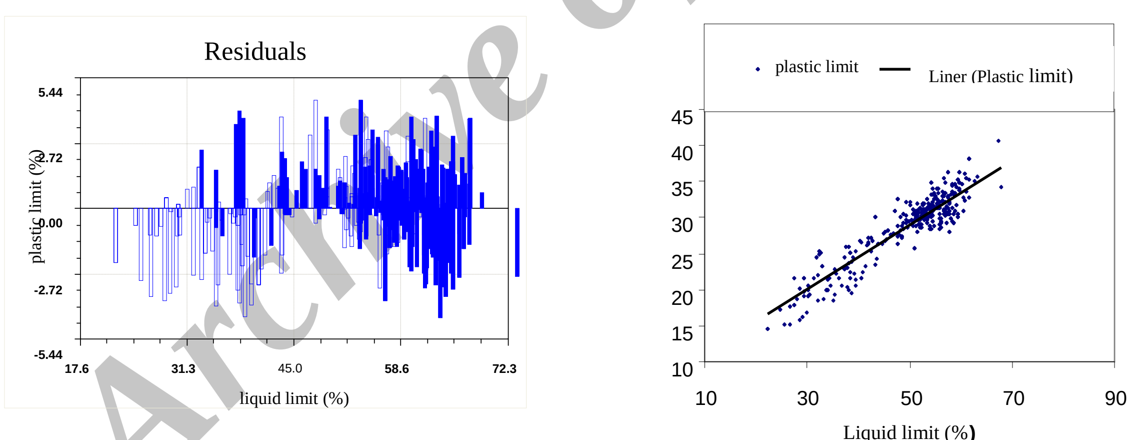

Figure 8. The relationship of liquid limit vs. plastic limit (left) and residual of PTF (right)

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Equation 4 shows the PTF for estimation of P_L based on L_L.

$$P_l = 6.843 + 0.445 \times L_l \qquad \text{(Equation 4)}$$

The average squared error (ASE) of the estimation of P_L is 2.42. The comparison of observed vs estimated P_L can be seen in Figure 9.

Based on the result of this research a computer program (SPPEN) was developed on Visual basic 6.0 for estimation of the soil physical properties.

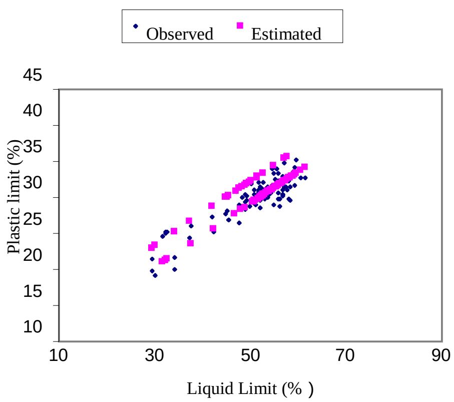

Figure 9. Comparison of the observed nd estimated data for the Plastic limit

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