ESTIMATION OF SOIL PHYSICAL PROPERTIES USING PEDOTRANSFER FUNCTIONS IN THE BANK OF YANGTZE RIVER OF CHINA

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ABSTRACT

One of the new techniques for predication of the soil physical properties (SPP) is Pedotransfer function (PTF). Generally, in this approach the SPP such as dry density, porosity, void ratio, soil hydraulic conductivity estimated by a semi-empirical equation. The problem is that the PTF estimation is more accurate for the region that the PTF was carried out and the number of the data which was been used. The objective of this research was developing some PTF for estimation SPP in bank of the Yangtze River, in Nanjing city, Jiangsu province, China. The SPP that 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. There were used 650 series of data for calibration and more 100 series data for verification. The result shows that most of SPP in the study area can be significantly estimate by wet density (ρ_w). For instant $\rho_d = 1.474 + 1.531 \times \rho_w$ and $L_l = 142.766 - 54.898 \times \rho_w$. Base on the result a computer program developed to estimate SPP.

Keywords: Soil physical parameter, pedotransfer function, Yangtze River, Nanjing.

INTRODUCTION

A broad array of methods currently exists to determine soil physical properties (SPP) in the field or in the laboratory. While measurements permit 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 exhibit substantial spatial variability in the soil hydraulic properties. It is virtually impossible to perform enough measurements to be meaningful in such cases, thus indicating a need for inexpensive and rapid ways to determine soil hydraulic properties (Schaap & Van Genuchten, 2001).

Many indirect methods for determining soil physical properties have been developed in the past. Most of these methods can be classified as pedotransfer functions (PTFs, after Bouma and van Lanen, 1987) because they translate existing surrogate data (e.g. particle-size distributions, bulk density and organic matter content) into soil physical data. All PTFs have a strong degree of empiricism in that they contain model parameters that were calibrated on existing soil physical databases. A PTF can be as simple as a lookup table that gives physical parameters according to textural class or include linear or nonlinear regression equations (e.g. Rawls and Brakensiek, 1985 and Minasny). 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 data set used to define the method (Donatelli et al., 1996 and 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 providence, 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 depth of the natural soil in bank of Yangtze River at Jiangsu province, Nanjing city, China at June 2005. Figure 1 shows the location of soil sample.

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

The total number of data was 750 series. Another material of this research was computer software such as spreadsheet (Excel) and statistical software (Curve expert, SPSS).

Methods

The soil physical properties were: 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 method. There is used 650 series of data for calibration and the other data (100) was used for verification. The process which used for data analysis and driving PTF was as follow: 1- Selecting two parameters (for example γ_w and γ_d), 2- Classification of the data, 3- Driving PTF by curve expert from the 650 series, 4- Analysis of variance (ANOVA) for PTF by SPSS, 5- Predication of target parameter by the 100 remaining data points and PTF, 6- Paired difference sample analysis of observed and predicted data

It used two statistical analyses for this 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.

RESULTS 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 was done on dry density. It used 650 series data for calibration. Figure 2 shows the dry density versus wet density for the calibration data as well as residual for the data.

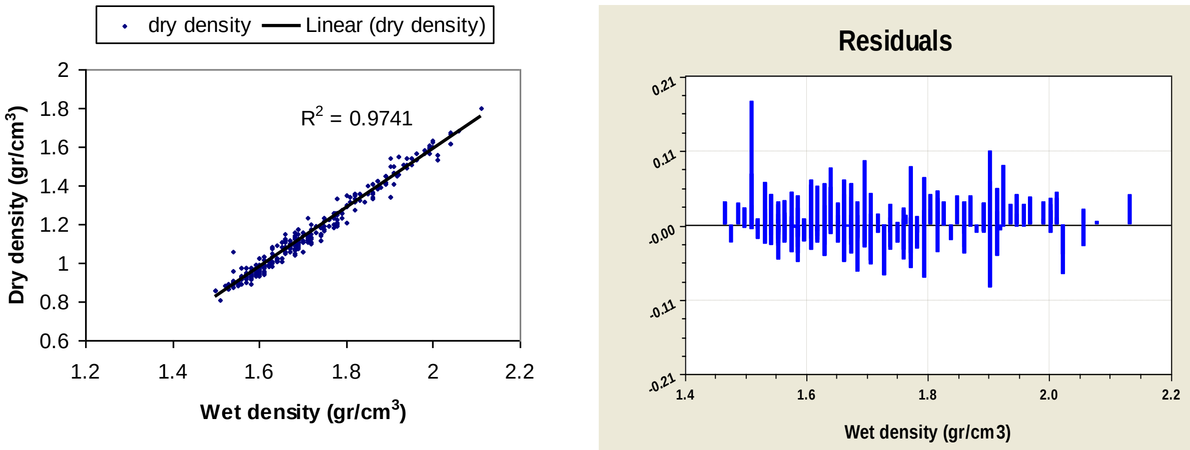


Figure 2- The relationship of wet vs. dry density (left) and residual of PTF (right)

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

$$\rho_d = 1.474 - 1.531 \times \rho_w \quad (1)$$

Analysis of variance (ANOVA) is done for the dry density data. It is shown is Table 1.

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	0.000
Residual	0.119	123	0.001		
Total	3.227	124			

It used 100 series data for the verification. For testing the ability of the data for predication of ρ_d it used the verification technique. The result of the verification presents in Fig. 3.

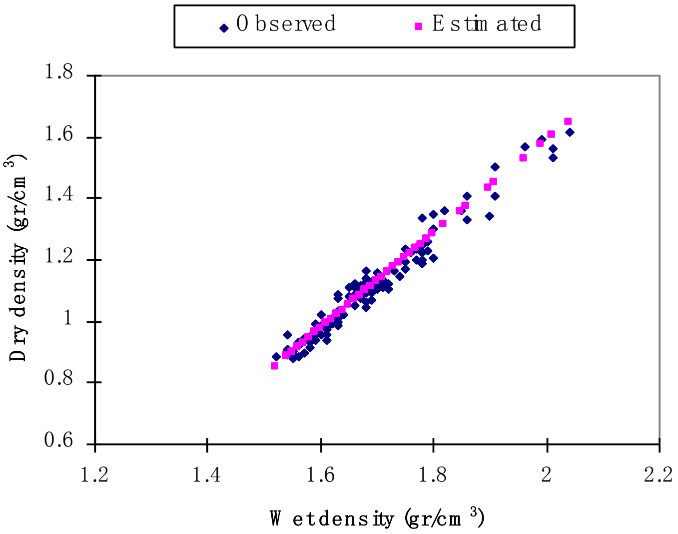


Figure 3- Comparison of the observed and estimated dry density for the verification data

The paired sample difference analysis (PSDA) test done by the SPSS software that the result 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 lee than 0.03. It confirms the last result too.

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			
-0.00014	0.03175	0.00284	-0.00576	0.00548	-0.049	124	0.961

Void Ratio

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

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

Figure 4 shows the void ratio versus wet density for the calibration data as well as residual for the data.

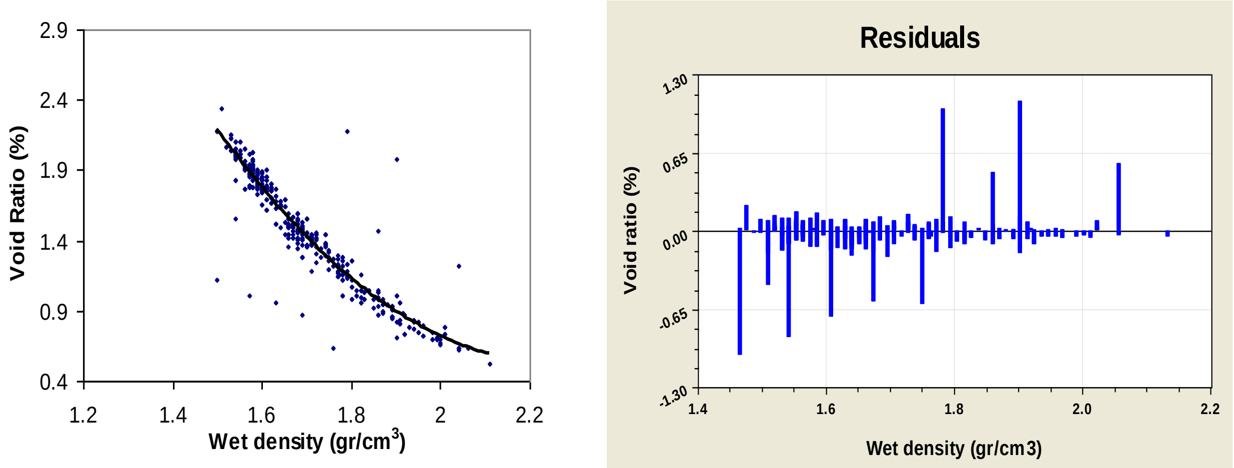


Figure 4-The relationship of wet density vs. void ratio (left) and residual of PTF (right)

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 presents in Fig. 5.

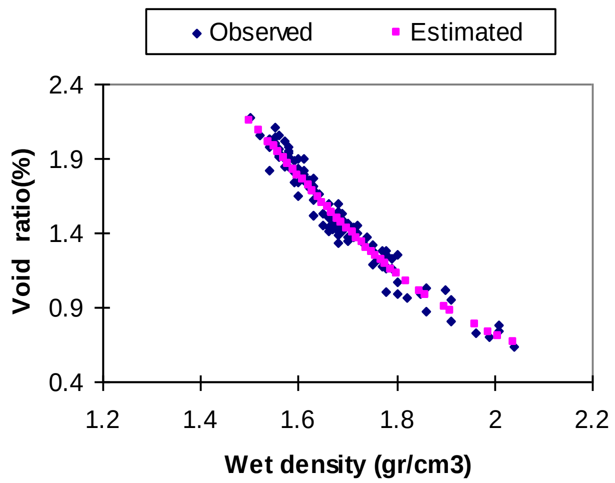


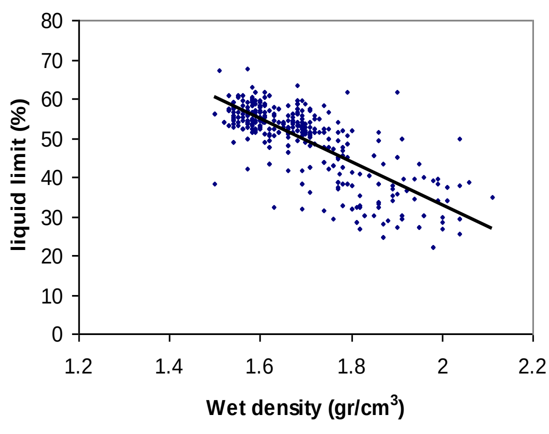
Figure 5- Comparison of the observed and estimated data for the void ratio

Liquid Limit

The similar procedure was carried out for liquid limit (L_L). Figure 6 shows the liquid limit Vs. wet density. The PTF, Eq. (3) offered for the estimation of L_L.

$$L_l = 142.766 - 54.898 \times \rho_w \qquad (3)$$

It shows that R squared is 0.77 and standard error is 5.33 for the calibration data. It can conclude that best PTF has 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 (e.g. Dry density, void ratio) but it not founded.



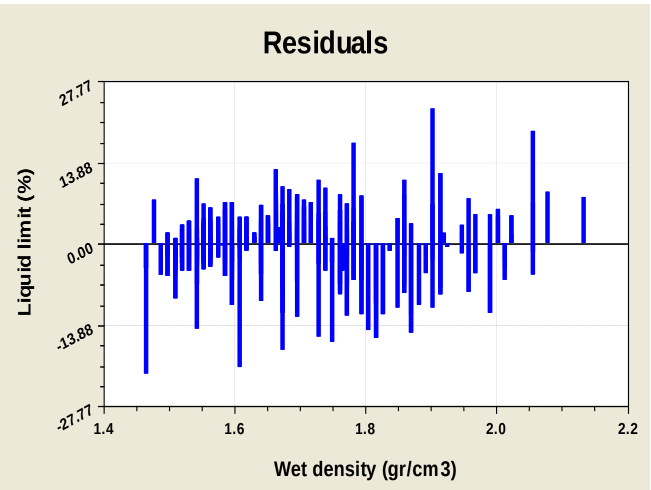


Figure 6- The relationship of wet density vs. liquid limit (left) and residual of PTF (right)

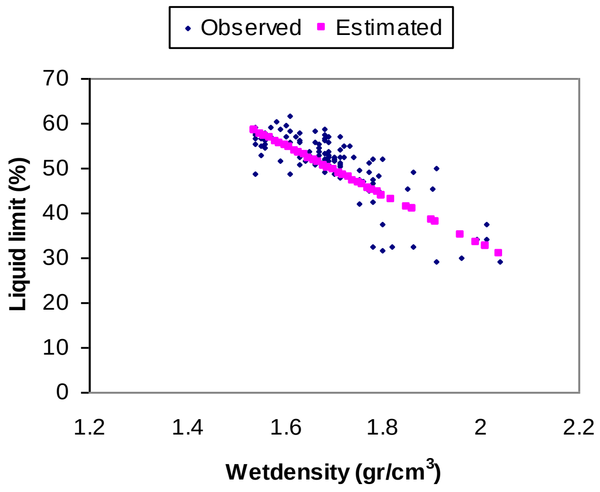


Figure 7- Comparison of the observed and estimated data for the liquid limit

Plastic Limit

The same procedure did for Plastic limit (P_L). The result shows that no acceptable PTF can be found for P_L Vs wet density. So it was tried to find a PTF with other parameter. The result shows that it can find a meaningful PTF on P_L and L_L. Figure 8 shows the P_L VS L_L. It shows that R squared is 0.90 and standard error is 1.73.

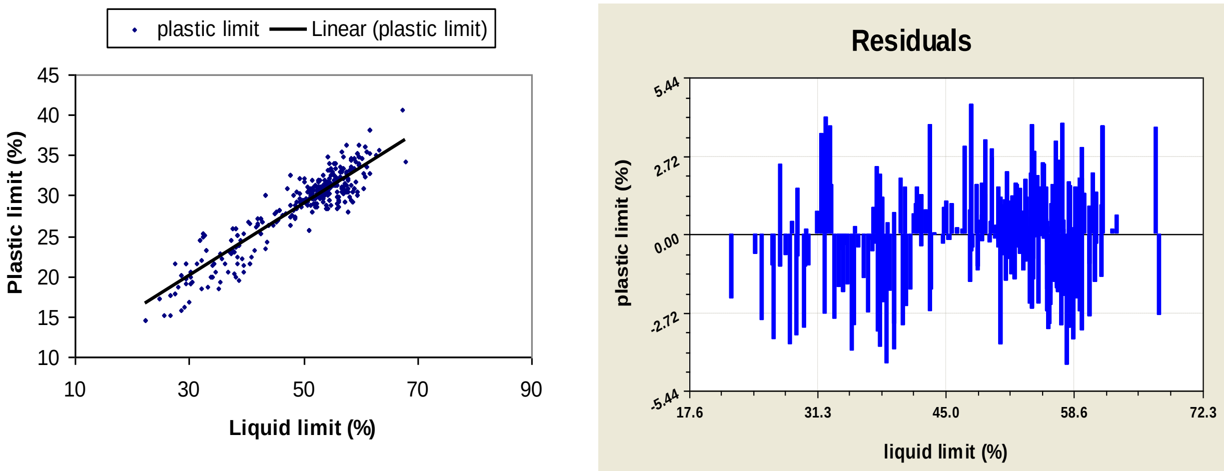


Figure 8- The relationship of liquid limit vs. plastic limit (left) and residual of PTF (right)

Eq. (4) shows the PTF for estimation of P_L base on L_L.

$$P_l = 6.843 + 0.445 \times L_l \tag{4}$$

The average squared error (ASE) of the estimation of P_L is 2.42. It can see in Fig. 9 the result of verification process.

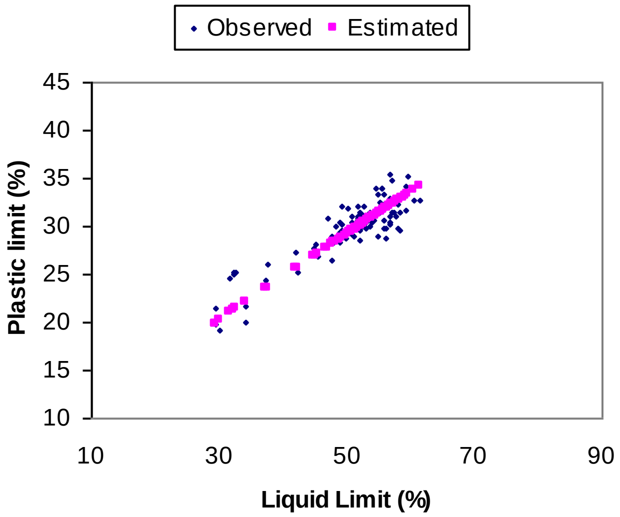


Figure 9- Comparison of the observed and estimated data for the Plastic limit

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

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