Application of Tangential Model to Various Types of Soils

タンジェンシャルモデルの種々の土への適用

〇Magatt THIAM*, Yuji KOHGO*, Hirotaka SAITO*

マガット　チャム*，向後　雄二*，斉藤　広隆*

Introduction: Modeling of soil water retention curves (SWRCs) is important in soil science and geotechnical engineering. Many researchers (Brooks and Corey, 1964; van Genuchten, 1980; Fredlund and Xing, 1994 etc.) proposed models for SWRC. Many of these have been compared to each other over the years and have shown that each has some advantages and limitations (Aubertin et al., 2003). The increasing number of numerical models imposes a demand on various SWRC models to simulate fluid flow and mass transport. In this paper, we will express the performance of a SWRC model named Tangential Model (TAMOD) proposed by Kohgo (1995). We also mention the merits and the parameters for various types of soils.

TAMOD: TAMOD ensures continuity of the slope *c* of the SWRCs and targets both positive and negative suction ranges, therefore, it is suitable for analyzing stability issues of slopes and soil structures, such as fill dams. In the exact discussions of the issues, it is necessary to estimate not only positive but also negative pore water pressures. An extended version of the TAMOD based on bounding surface concept (Kohgo, 2008) is also proposed and it may handle cyclic behavior of SWRC, namely drying, wetting and scanning curves. In the extended TAMOD, the same parameters as those of the original TAMOD are used. Parameters of TAMOD are coordinates and slopes at 3 points: points E, M and F as shown in Fig. 1. These points are as follows: (i) Point E: at air entry value; (ii) Point M: at maximum specific moisture capacity c_m=c_{max}; (iii) Point F: at critical suction and degree of saturation. The model is shown in Fig.2

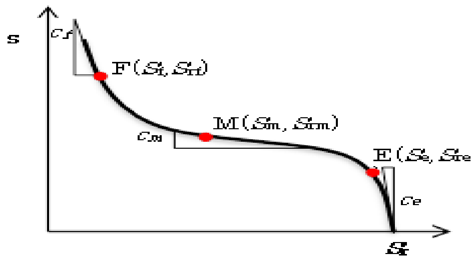

Fig. 1: A typical SWRC and TAMOD model

$$S_r = S_{re} + c_e\left(s_e - \frac{P_a s}{P_a - s}\right) \quad \text{for } s \le 0 \qquad (1);$$

$$S_r = S_{re} + c_e(s_e - s) \quad \text{for } 0 < s \le s_e \qquad (2)$$

$$S_r = S_{re} - c_e(s - s_e) - \frac{(c_m - c_e)(s - s_e)^{m_r+1}}{(m_r+1)(s_m - s_e)^{m_r}} \quad \text{for } s_e < s < s_m \qquad (3)$$

$$S_r = S_{rf} - c_f(s - s_f) - \frac{(c_m - c_f)(s - s_f)^{n_r+1}}{(n_r+1)(s_m - s_f)^{n_r}} \quad \text{for } s_m \le s < s_f \qquad (4)$$

$$S_r = S_{rf} - c_f(s - s_f) \quad \text{for } s \ge s_f \qquad (5)$$

Fig.2: TAMOD equations: *P*a is atmospheric pressure; m_r and n_r are calculated from coordinates of points E, M and F.

Material and method: For estimating TAMOD parameters (s_e, S_{re}, s_f, S_{rf}, s_m, S_{rm}, c_m and c_f) of various soil types, SWRC data from UNSODA were used. In this model, it is necessary to graphically choose 3 points on the curve obtained from experimental data and estimate the slopes at the 3 points. Values of the slopes are adjusted in order

＊United Graduate School of Agricultural Science Tokyo University of Agriculture and Technology, 東京農工大学連合大学院

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to get the best fit passing through the data points. Kohgo (2008) used 3 soil samples to assess the performance of the model. In this paper 150 soils were used: 44 sands, 28 sandy loams, 24 clays, and 13 loamy-sands and 41 silty-loams.

Results: In this paper, only some results from sandy soils and sandy loam soils are presented. They are representative of the soil water retention curves, yet analyzed. Figs. 3 and 4 show the results for 2 Sands and sandy loam. TAMOD parameters for sand, sandy loams, loamy sands and silty clays have been determined. The results show that the model fits well the data for suction between 0 and 104 kPa.

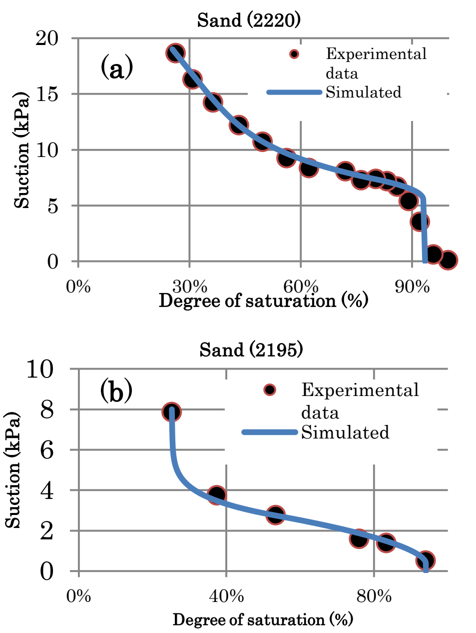

Fig. 3: (a) SWRC of sand number 2220; (b) SWRC of sand number 2195

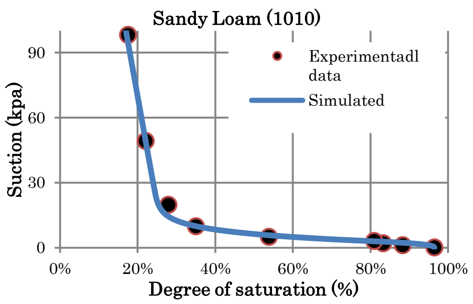

Fig. 4: SWRC of sandy loam number 1010

Table1: TAMOD parameters of some sands from UNSOD

Code	S_e	S_{re}	S_m	S_{rm}	S_f	S_{rf}	C_m	C_f
2250	0.500	96.0	0.687	54.0	1.177	12.5	2.000	0.050
2251	0.500	96.0	0.687	54.0	1.177	12.5	5.000	0.050
2252	0.500	96.0	0.687	54.0	1.177	12.5	4.000	0.050
2253	0.500	78.2	0.687	33.7	1.472	09.4	2.000	0.050
3070	2.354	69.8	3.041	42.1	4.316	05.1	0.300	0.030
3080	3.335	99.	4.218	70.6	4.709	39.9	0.600	0.030
2197	0.588	84.8	1.275	63.1	5.886	22.4	0.300	0.001
2220	5.495	93.0	7.357	80.1	18.639	26.2	0.145	0.024
2221	0.200	92.0	5.591	69.5	23.544	16.1	0.100	0.004
3350	0.981	80.	9.810	36.0	98.100	14.9	0.019	0.000

S_{re}, S_{rm}, S_{rf}: degree of saturation (%); s_e, s_m, s_f: suction (kPa); c_m and c_f: slope (%/kPa)

Table 1 shows the TAMOD parameters of some sands. Similarity of the parameters of the sands 2250, 2251 and 2252 might be justified by closeness of their bulk density values.

By analogy to the residual and saturated water content, parameters s_e, S_{re}, s_f and S_{rf} may be regarded as fitting parameters in the sense that they govern the range of the simulated curve. s_m, S_{rm} and the slopes values are critical parameters governing the curve shape. We will investigate possible correlation between these parameters and some soil basic soil properties and analyze the statistical significance of the entire parameters yet estimated.

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