Prediction of SWC of some Residual Soils in Thailand Based on Grain Size Curves

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ABSTRACT: Rainfall-triggered landslide will continue to pose serious threats to slopes in Thailand with the current climate change situation. To understand the mechanisms of such slope failure and develop a proper mitigation approach, the properties of residual soils in unsaturated state need to be fully characterized. This paper reports on laboratory results of Soil-Water Characteristic Curve (SWCC) of some residual soils in Thailand together with their prediction based on grain size distribution (GSD) curve. Miniature tensiometers as well as relative humidity sensors were used in determining the SWCC on undisturbed samples. Arya and Paris (1982) approach has been used to develop SWCC based on GSD. Excellent correspondence between the experimental and predicted curves was obtained.

1 INTRODUCTION

Landslides have been one of the frequent geohazards affecting the hilly and mountainous terrains, in Thailand. A number of causal factors have been identified to be responsible for landslide occurrences and have been categorized as preparatory and triggering causal factors with respect to their effect (Popescu, 1994). On this basis, rainfall has well been recognized as the main triggering factor for landslides in Thailand causing shallow translational slides. To understand the mechanisms of such slope failures and develop proper mitigation approaches, the properties of residual soils in unsaturated state need to be fully characterized

The soil-water characteristic curve (SWCC) is the key property of unsaturated soils assisting the geotechnical engineer in charactering the functional properties of which a detail description could be found at Fredlund and Rahardjo (1993). An experimental program was undertaken thus to determine the basic and index properties including the soil water characteristics of residual soils collected from Northern Thailand, in their absence. Then, the predictability of soil water characteristics from particle size distribution was investigated.

2 SAMPLING PROGRAM

A sampling program was carried out in Nan and Mae Hong Son Provinces in Northern Thailand. Having identified 6 lithologic units in Nan Province and 13 of them in Mae Hong Son Province, 19 pits of essentially more than 2.0 m of depth were excavated in each lithologic unit that is representative for each unit and undisturbed block samples of 200 mm side were extracted.

3 BASIC AND INDEX PROPERTIES

3.1 *Test Procedures*

Out of the 3 block samples each extracted from the 19 test pit locations one was, first, used to conduct basic property and index testing and thereby to select the samples for soil water characteristics testing based on their particle size distributions to avoid as much as possible the influence of scale effects on testing. Basic property and index tests were carried out at the Geotechnical Laboratory of Asian Institute of Technology.

3.2 *Test results*

Grain size distributions of the residual soils are plotted collectively and presented in Figs.1 and 2, province wise.

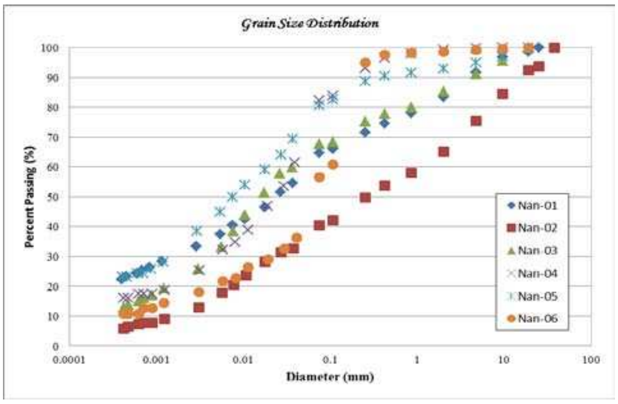

Fig. 1 Grain Size Distributions of the Residual Soils from Nan Province

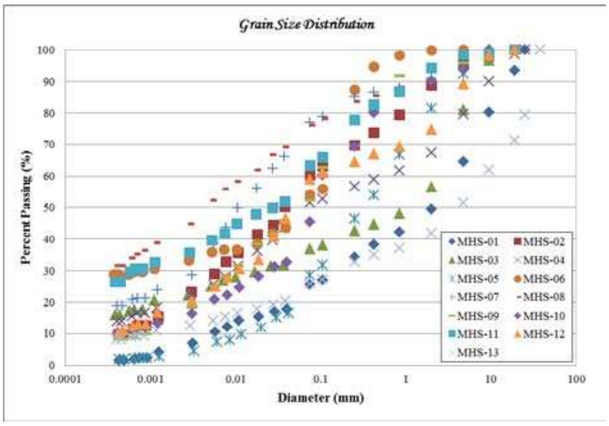

Fig. 2 Grain Size Distributions of the Residual Soils From Mae Hong Song Province

Grain size distribution curves of the residual soils which are flatter illustrate that constituent grain sizes of almost all samples vary widely from clay size to gravel size particles. Further, the grain size distributions of all samples were found to exhibit gap-grading in varying degrees leading to bimodality in their distribution. The Fredlund et al. (2000) equation for bimodal grain size distribution curves was capable of modeling all the grain size distribution with excellent goodness of fit.

Six residual soils out of the 19 collected samples were identified to be coarse grained with percent passing No. 200 sieve less than 50%. One of them is from Nan Province; Nan 02 while the rest are from Mae Hong Son Province; MHS 01, 03, 05, 10, and 13.

The experimental grain size distribution curves, with their potential to be used as a basis for estimating the soil water characteristics, were modeled as continuous functions of grain size. The observed bimodality or the double hump characteristics in the grain size curves were captured satisfactorily using the bimodal equations of Fredlund et al. (2000).Fig. 3shows the best fit curve for one sample from Nan province (Nan-01) with the associated parameters. Derivation of the bimodal model curve is by stacking two unimodal models. The parameter "w" in the plot is the weighting factors of the sub curves with 0 < w <1. It can be noted from the figures that this parameter for those residual soils which were identified as coarse grains were turned out to be in the lower half range (w < 0.5).a_{bi}, n_{bi}, m_{bi}, which are, respectively, related to initial breaking point, steepest slope, and the shape of the first sub curve and corresponding parameters of the second sub curves, j_{bi}, k_{bi}, l_{bi}, obtained for the residual soils are presented collectively in Table 1. Also in the table are d_{rbi} and d_m,the parameter related to the amount of fines and the minimum allowable size particle.

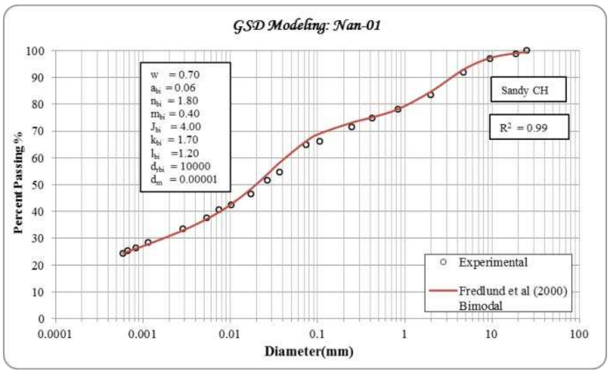

Fig. 3 Grain Size Distributions modeling of the Residual Soils From Nan 01

4 SOIL WATER CHARACTERISTICS

4.1 *Testing and Prediction*

7 residual soil samples selected for soil water characteristics testing. 3 samples were from Nan Province out of the 7 selected.

The experimental determination of the soil water characteristics curves for the full range of suction, from 0 to 1,000,000 kPa, in this study was divided into two parts; the region where the suctions are less than approximately 100 kPa, and the region where the suctions are greater than 1000 kPa and up to 1,000,000 kPa.

Table 1. Parameters from grain size distribution curves

	w	abi	nbi	mbi	jbi	kbi	lbi	drbi	dm	R^2
MHS-01	0.2	0.11	7	0.5	11	2	0.8	1000	0.0004	0.99
MHS-02	0.5	0.03	0.9	1.2	6	2.2	0.15	10000	0.00001	0.99
MHS-03	0.3	3.1	21	0.08	6	3	0.59	1000	0.0001	0.99
MHS-04	0.59	0.08	1.2	0.7	8	4	0.9	10000	0.00001	0.99
MHS-05	0.3	0.02	1.5	11	2.5	1.5	0.9	1000	0.0004	0.99
MHS-06	0.8	0.26	29	0.22	0.08	9	0.2	10000	0.00001	0.99
MHS-07	0.6	0.02	1.35	1.5	6	2.7	0.2	10000	0.00001	0.99
MHS-08	0.55	0.03	0.9	1.2	6	2.2	0.15	10000	0.00001	0.99
MHS-09	0.6	0.04	1	1	0.8	2.2	1	10000	0.00005	0.99
MHS-10	0.4	0.1	2	1.4	1.77	1.5	0.5	1000	0.0001	0.99
MHS-11	0.55	0.12	3.1	0.24	1.4	1.3	0.7	10000	0.00001	0.99
MHS-12	0.55	0.05	1.8	0.75	5	3	0.6	10000	0.00001	0.99
MHS-13	0.6	4	1.1	0.6	20	3	3	10000	0.00005	0.99
Nan-01	0.7	0.06	1.8	0.4	4	1.7	1.2	10000	0.00001	0.99
Nan-02	0.2	0.01	1.3	7	10	0.98	0.75	1000	0.0001	0.99
Nan-03	0.74	0.03	1.1	0.95	5.2	1.8	0.93	10000	0.00001	0.99
Nan-04	0.65	0.04	1.4	1.95	0.1	5	0.07	10000	0.00007	0.99
Nan-05	0.88	0.05	1.3	0.6	10	2	0.58	10000	0.00001	0.99
Nan-06	0.52	0.08	2	2	0.26	10	0.2	10000	0.00009	0.99

Wetting and drying SWCC were established using 50mm diameter and 50mm high cylindrical specimens extracted from block samples and the tests were conducted at the Geotechnical Laboratory of the Kasetsart University of Thailand.

The physic-empirical Arya and Paris (1981) approach was used to predict the soil water characteristics. Partitioning of the particle size distribution curves, as required, was carried out conveniently by making use of the continuous functions obtained from Fredlund et al. (2000) model.

4.2 *Results*

The experimental points corresponding to wetting and drying soil water characteristics of the residual soil selected from Mae Hong Son Province (MHS-02) quantified is shown in Fig. 4. The bimodal soil water characteristics shown there in corresponding to the bimodal grain size distribution was then modeled using Gitirana and Fredlund (2004) model shown in the same plot as continuous lines. It can see that the soil water characteristics are very well captured by the model. The volumetric water content corresponding to the saturated conditions, θ_s, were arbitrarily chosen to be plotted against a suction of 0.1 kPa. The presence of occluded air might not necessarily make θ_s to be the porosity of soils.

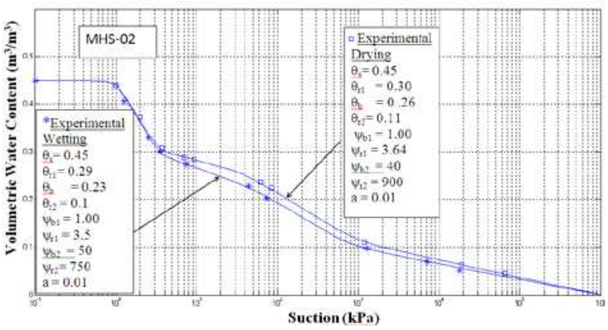

Fig. 4 Soil water charecteristics curve for MHS-02

The key features of the soil water characteristics curves including the air-entry values and the residual volumetric water contents as determined from the Gitirana and Fredlund (2004) model are summarized in Table 2.

Table 2 Key Features of the SWCC

Sample	AEV(kPa)	θs	θ_{r1}	θ_{sr2}
NAN-01	2	44.89	43	19
NAN-03	1	43.6	30	6
NAN-04	1.2	54.29	41	25
MHS-02	1	45	29	10
MHS-07	1.2	48.72	42	24
MHS-08	0.9	41.51	31	10
MHS-12	0.7	47.4	27	10

The selected samples from Nan Province yielded an air-entry value ranging from 1 to 2 kPa. In Mae Hong Son Province, the corresponding value ranged from 1.1 to 1.9.

Such low air entry values can again be attributed to the structured nature of materials which have been classified as fine grained. In general, residual water content has a decreasing trend with the decrease of fines content.

Fig. 5 shows the comparison between the best fit Gitirana and Fredlund (2004) wetting soil water characteristics curves and that predicted using Arya and Paris (1981) model.

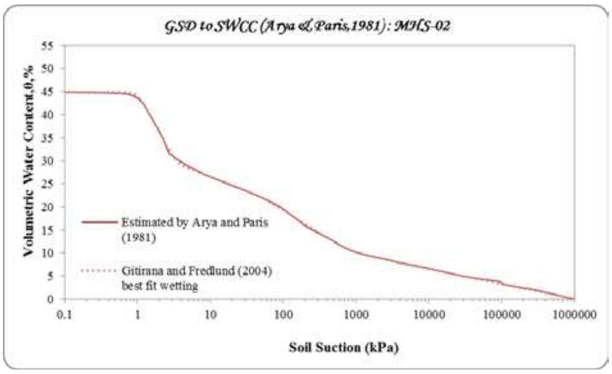

Fig. 5 Modeling of Grain Size Distribution MHS-02

Excellent correspondence between the experimental and predicted curves was obtained.

The variation of the empirical parameter, (α), as obtained for the above predictions, is shown in Fig.6.

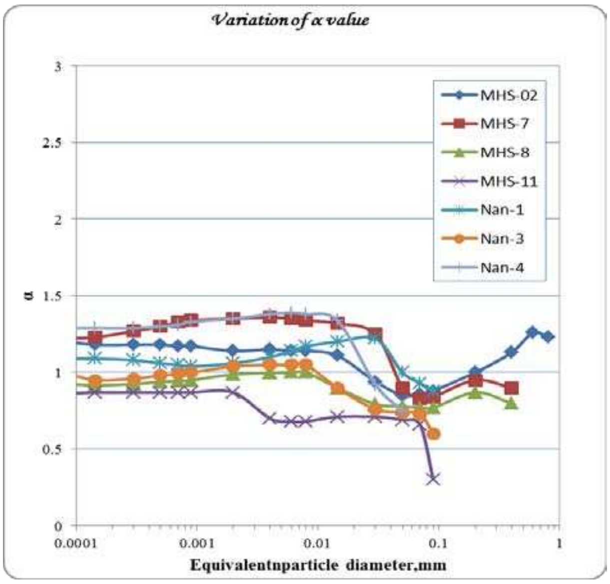

Fig. 6 Variation of α Values of the Selected Samples

All curves have more or less the same pattern. Initial α value for the selected samples varies in the range of 0.87 to 1.29 and tend to increase slightly with the equivalent particle diameter until it reach a maximum value in the range of 0.01 mm 0.07, except for the sample from MHS 11. Thereafter, the values tend to decrease quite rapidly and generally flatten. For the sample from pit MHS 11 the maximum value can be observed at an equivalent particle diameter of 0.01 mm. Initial α values can be generally noted to be decreasing with the decreasing fines content for the tested soil.

5 CONCLUSIONS

Soil water characteristics obtained for the full range of suction from the experimental program were featured with low air entry values of less than or equal to 2 kPa attributed to their structured nature. Like the grain size distribution curves, the soil water characteristics curves also exhibited similar yet pronounced characteristics of bimodality owing to the structured nature of materials. The characteristics of experimental soil water characteristic curves are captured very well by Gitirana and Fredlund model for bimodal soil water characteristics curves. Moreover, the wetting soil water characteristics curve obtained from grain size distribution and their packing using the physic empirical, Arya and Paris approach gave excellent results. However, the fitting parameter, α, was found to vary from 0.87 to 1.29 depending on the structural characteristics of the residual soils tested.

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