Engineering Properties of Residual Soil from Landslide Hazard Area in Ban Nong Pla Village, Chiang Klang District, Nan Province, Northern Thailand

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Abstract

Landslide is one of natural disasters commonly happened in Thailand every year. On 23 August 2006, landslide was initiated in many areas of Nan province, northern Thailand after five days of the unusual heavy rainfalls. This event destroyed many houses, buildings and infrastructures. In this paper, we analyzed geological and engineering properties of residual soil derived from sedimentary rocks in this potential landslide zone, especially at Ban Nong Pla Village, Chiang Klang district. The properties of residual soil we analyzed included specific gravity, grain size distribution, liquid limit, plastic limit, plastic index, total unit weight and moisture content. Engineering properties included analysis in shear strength parameters were also carried out. As a result, the average moisture content in soil is of 24.83 %, the average specific gravity is 2.68, 44.93 % of the liquid limit, 29.35 % of plastic limit and 15.58 % of plastic index. Soils were classified using Unified Soil Classification System (USCS) as ML- CL, CL- ML, ML- OL, SC and SM. The cohesion of soil is between 0.096 - 1.196 ksc and angle of internal friction 11.51 - 35.78 degree, respectively.

Keywords: Landslide, Multi-stage direct shear test, Shear strength, Nan

1. Introduction

Landslide is one of the natural disasters causing the damage to life and casualties in Thailand every year. A number of factors commonly triggered the landslide includes heavy rainfall during tropical monsoon season, geological conditions and change of land uses. The direct economic lost of the country due to landslide was calculated to be equal to 100 million Baht per year and the return period of landslide is once in every 3-5 years (Soralump and Thowiwat, 2009).

Ban Nong Pla village is located within the valley with steep slope and high elevation. The main study area is surrounded by mountains with high of 700 -1200 meters above the present mean sea level. Direction of channel flow within the sub-watershed is mainly from southeast to northwest and mostly joins into the Huai Nam Puea catchment (figure 1). Populations in the area are mainly farmers including rice plantation, lychee and corn for animal feeding. The development tends to move higher to the mountain and changing of the land use and land cover tend to trigger the landslide in the area such as shown in figure 2.

2. Objectives and method

This paper focuses on the analysis of engineering and physical properties of residual soil from parent rocks. The relationship between shear strength with moisture content behavior of residual soils was carried out in order to find the safety factor of the soil slope. Field survey was carried out to collect disturbed and undisturbed samples of residual soil. Laboratory analyses included physical and engineering properties testing. Classification of soil is based on USCS. The properties of residual soil we analyzed included specific gravity, grain size distribution, liquid limit, plastic limit, plastic index, total unit weight, moisture content. Engineering properties included shear strength parameters. Soil sampler (Mairaing et al., 2005) was designed to collect the residual soil samples (figure 3). We set up area ratio of the sampler to about 18 % to ensure the limited disturbance of soil samples. Undisturbed soil samples (figure 4) were collected using KU-Miniature sampler. Undisturbed soil sample is collected at the interface level between bed rock and residual soil (9 test pits) for testing find the shear strength parameter including consolidation drained test (8 test pits) and consolidation undrained test (1 test pits). Disturbed soil samples (11 samples) were also collected for testing the physical properties and permeability following the American Society for Testing and Materials (ASTM) including total unit weight, water content test (ASTM D 2216), specific gravity test (ASTM D854), sieve analysis test (ASTM D422), hydrometer test (ASTM D 422), Atterberg's limits test (ASTM 4318).

"Multi-stage direct shear test" was applied to this study in order to find shear strength of undisturbed samples. Three samples were applied for the general direct shear test (conventional test). "Mohr - Coulomb failure envelope" is assigned to obtain the value of shear strength parameter (c', ϕ'). It is noted that Multi-stage direct shear test will capable for shearing the sample until it is nearly to the failure point in each normal load (at least three or four normal loads). This testing method suitable for sample with high variability and in case requires less amount of sample (Mairaing, 2008).

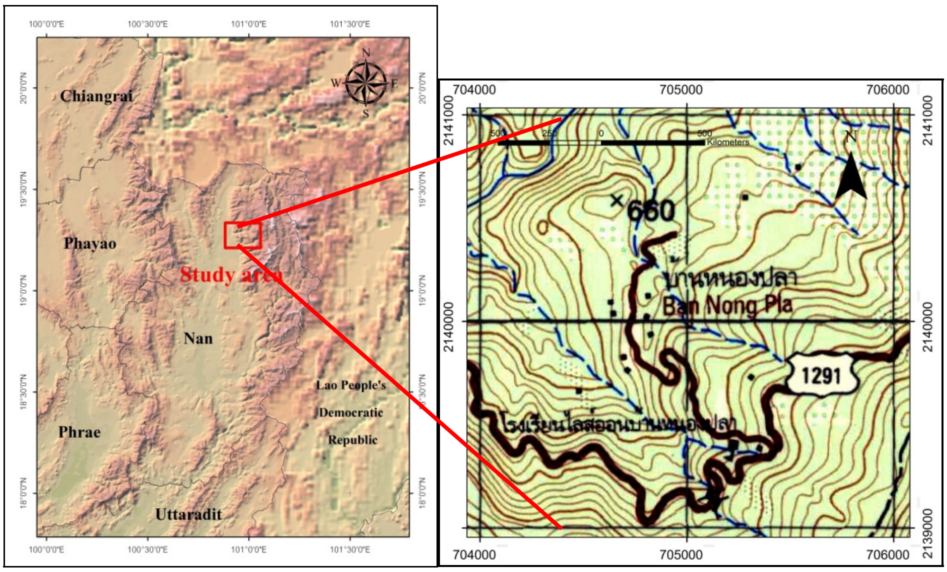

Figure 1. Ban Nong Pla village of Chaing Klang district, Nan province.

Figure 2. Oblique aerial view of Ban Nong Pla village showing steep slope valley and plantations in high elevation.

Figure 3. KU - miniature sampler (Mairaing et al., 2005).

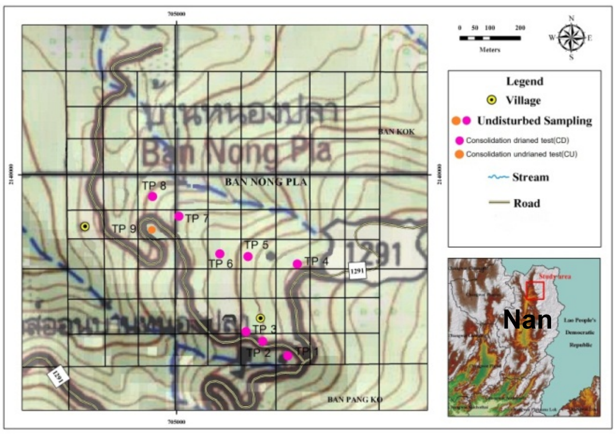

Figure 4.Undisturbed soil sample location.

3. Results

3.1 Physical properties

Results from grain size analysis are expected to help classifying soils, especially coarse materials. It is also benefit to analyze whether or not the soil consists of predominantly gravel, sand, silt, or clay, and to a limited extent, which of these size ranges is likely to control the soil engineering properties. Grain size analysis is shown in figure 5 and table 1. Results of grain size distribution analysis from 11 samples of residual soil derived from weathered parent rocks such as shale, siltstone and sandstone have shown high percentage of fine grained texture and have the characteristic of distribution gap grade and uniform grade.

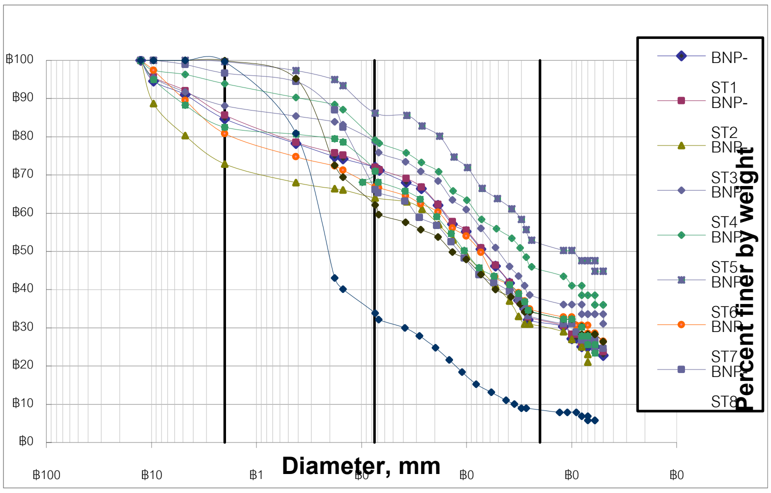

Figure 5. Grain size distribution of residual soil samples.

Table 1. Physical properties of 11 disturbed samples.

Parent rock	Test Pit	WC %	G_s	Porosity %	Atterberg's limits			USCS
					LL	PL	PI	
shale	BNP-ST1	20.31	2.67	44.56	46.56	29.86	16.70	ML- CL
shale	BNP-ST2	26.91	2.67	51.86	45.33	28.92	16.41	ML- OL
shale	BNP-ST3	30.52	2.69	46.80	47.35	30.55	16.80	ML- CL
shale	BNP-ST4	31.74	2.69	47.74	47.35	33.94	13.41	ML- CL
siltstone	BNP-ST5	27.89	2.69	50.32	45.57	31.69	13.88	CL- ML
siltstone	BNP-ST6	22.66	2.70	48.70	46.19	28.33	17.86	CL- ML
shale	*BNP-ST7	25.76	2.66	-	45.37	27.05	18.32	ML- OL
siltstone	BNP-ST8	20.92	2.66	44.31	38.33	26.26	12.07	ML- CL
siltstone	BNP-ST9	17.52	2.67	45.79	39.88	25.97	13.91	SC
shale	BNP-ST10	26.56	2.67	46.56	47.35	30.96	16.39	ML- CL
sandstone	*BNP-ST11	22.36	2.70	52.10	-	-	-	SM

Remarks: *BNP - ST 11 is Non plastic, *BNP – ST 7 cannot collect disturbed sample for testing porosity.

From Table 1, the average moisture content of soil, the average specific gravity of soil, the average liquid limit, and plastic limit are 24.83%, 2.68, 44.93 % and 29.35 %, respectively. Plastic index is 15.58 %. The Atterberg's limit of 11 samples from parent rocks can be concluded that most of residual soils in the study area owns the low plasticity (LL< 47 % and PI = 15.58 %). It is indicated the content of kaolinite as clay mineral in soil (figure 6). Soil can be classified by Unified Soil Classification System as ML- CL, CL- ML, ML-OL, SC and SM, respectively. Residual soil from shale can be classified into ML- CL, ML-OL. Most of disturbed soils sample are silty clay and clayey soil, silty clays and organic silt clays soil. Residual soil from siltstone can be classified into CL- ML, SC because disturbed soil sample is characterized by clayey fine soil and silty clay, clayey sands and poorly graded sand-clay mixtures. Residual soil from sandstone including the sample BNP-ST11 can be classified into SM because disturbed soil sample is dominated by silty sand soil and poorly graded and that is not plasticity (non plastic).

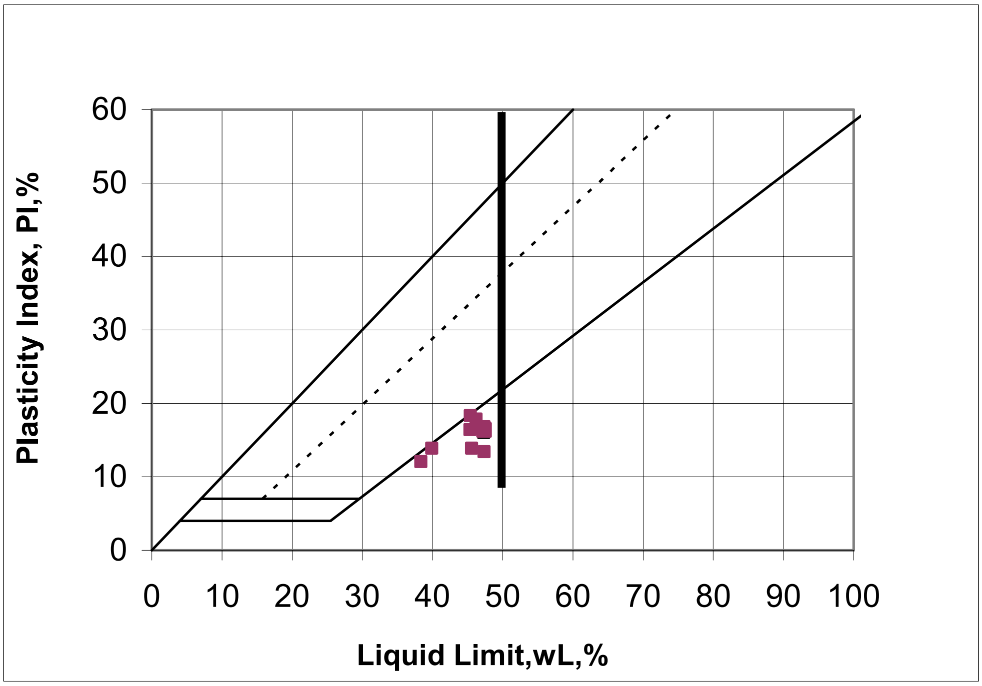

Figure 6. Plasticity chart of residual soil samples from this study.

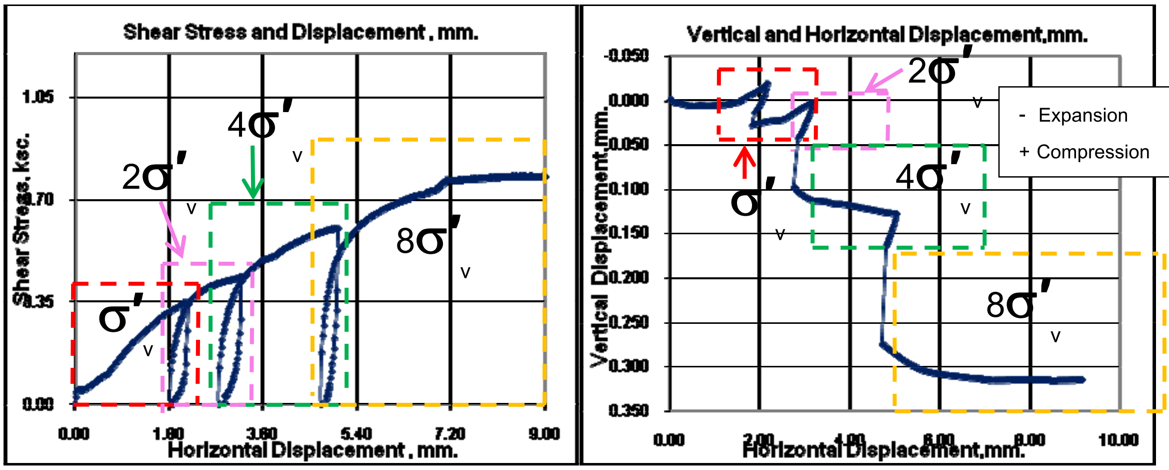

Figure 7. Stress -Strain from multi- stage direct shear test.

Table 2. Results of testing shear strength from soil at natural moisture content using the consolidation drained test.

Test Pit	Water content %	Depth(m)	Degree of weathering	c' (ksc.)	ϕ' (Degree)
TP 1	22.02	2.0	Grade V	0.233	14.77
TP 2	23.75	2.5	Grade V	0.316	20.47
TP 3	22.85	2.5	Grade V	0.501	25.30
TP 4	33.04	0.8	Grade VI	0.433	23.80
TP 5	27.57	0.6	Grade V	0.455	11.51
TP 6	26.87	1.0	Grade VI	0.522	17.82
TP 7	19.98	0.8	Grade VI	0.714	15.17
TP 8	15.81	1.2	Grade VI	0.418	21.90

Table 3. Results of testing shear strength of soil at natural moisture content using the consolidation undrained test.

Test Pit	Water content %	Depth(m)	Degree of weathering	c (ksc.)	ϕ (Degree)
TP 9	11.97	3.0	Grade V	0.617	22.29

3.2. Engineering properties

3.2.1 Initial water content condition

Testing result multi-stage direct shear test (CDtest and CU test) at natural moisture content is shown in Tables 2 and 3.

From Tables 2 and 3, the consolidation drained and consolidation undrained tests in the natural water content condition is clearly shown that cohesion value has tendency of increasing when the degree of saturation has low value. The cohesion of soil value is between 0.223 to 0.714 ksc and friction angle is 11.51 to 25.30 degree (CD test). The cohesion of soil value is 0.617 ksc and friction angle as 22.29 degree (CU test).

3.2.2 Varies degree of saturation

The results of testing the effective shear strength of residual soil in vary degree of saturation, S_r, are of 3 levels: 60%, 80% and 100% or KU-MDS test (Soralump and Thowiwat, 2009). This is applied for finding the properties of the soil shear strength decreases when the moisture content increases. After the testing multi-stage direct shear at natural moisture content of all test pits, the sample at moisture content levels of degree of saturation and testing multi-stage direct shear of sample in each test pit was carried out. Testing result is shown in table 4 for consolidation drained test and table 5 for consolidation undrained test.

From Table 4, the consolidation drained direct shear tests at varies degree of saturation (KU-MDS test) are clearly shown that the cohesion value has tendency of decreasing when the degree of saturation has high value. The cohesion of soil value is 0.09 to 1.19 ksc and friction angle as 11.51 to 35.78 degree. From Table 5, it can be concluded that he consolidation undrained direct shear tests at varies degree of saturation (KU-MDS test) are clearly shown that cohesion value has tendency of decreasing when the degree of saturation has high value. The Cohesion of soil value is between 0.18 to 0.61 ksc and Friction angle as 19.45 to 29.8 degree, respectively.

4. Discussion

Physical properties of weathered residual soil from parent rock were tested with special attention to study the feasibility and the opportunity of landslide. As a result, residual soil from weathered parent rocks such as shale, siltstone and sandstone occurred in this study area includes high percentage of fine grained texture and the characteristic of distribution is shown as Gap grade and Uniform grade (also see figure 5).

Most of residual soils in the study area owns the low plasticity (LL< 47 % and PI = 15.58 %) and shows the test results in plasticity chart (also see figure 6). It indicates kaolinite and clay mineral in soil that can be classified by Unified Soil Classification System including ML- CL, CL- ML, SC and SM. It is meant that the toughness properties of soil will be changed whenever the moisture content increases, event just a little increase (Hazelton and Murphy, 2007). This soil type is risky to cause the landslide.

This research found that the properties of soil shear strength decreases when moisture content increases (see tables 4 and 5). The consolidation drained testing of cohesion of soil ranges from 0.096 to 1.196 ksc of residual soil from shale and siltstone and 0.18 to 0.617 ksc from sandstone. Therefore, total cohesion of soil decreases when the volume of moisture content in soil increases. Moisture content is an important factor affecting the shear strength of the soil. Soil mass with dry conditions or low moisture content will own higher soil shear strength. Soil shear strength will decrease when moisture content in soil increases.

The volume of water increase will disturb surface tension in soil making cohesion of soil decreases and the volume of water, then, increases. A friction between soil particles, then, reduces to which soil shear strength will decrease and impact directly to the stability of soil slope.

Table 4. Results of testing shear strength of soil at degree of saturation using the consolidation drained test (KU – MDS test).

Degree of saturation, %	40 - 60		60 - 75		75 - 90		75 - 90	
	c′	ϕ′	c′	ϕ′	c′	ϕ′	c′	ϕ′
TP 1	0.31	20.47	0.28	12.33	0.22	14.77	0.19	21.58
TP 4	1.19	20.84	0.45	11.51	0.43	23.08	0.09	35.78
TP 8	0.40	21.90	0.71	15.17	0.32	13.08	0.14	19.79

Table 5. Results of testing shear strength of soil at degree of saturation using the test pattern consolidation undrained test (KU – MDS test).

Degree of saturation, %	30 - 50		60 - 75		75 - 90		75 - 90	
	c	ϕ	c	ϕ	c	ϕ	c	ϕ
TP 9	0.61	22.28	0.53	29.80	0.43	19.45	0.18	25.34

5. Conclusions

1. Soils in the study area are mainly the weathering product from clastic sedimentary rocks including shale, siltstone and sandstone.

2. Most of residual soils in the study area are composed of silty sand soil, silty clay soil and clayey fine soil which can be qualified to poor drained soil. This soil character is able to easily adsorb rain water, then, results in the decrease of shear strength leading to cause the landslide.

3. Most of residual soils in the study area is characterized by low plasticity (LL< 47 % and PI = 15.58 %). This means the toughness properties of soil can change when moisture content increases, even just a little increase. This is also risk for landslide.

4. The cohesion of soil ranges from 0.096 to 1.196 ksc and angle of internal friction is between 11.51 to 35.78 degrees. Consolidation undrained testing (amount 1 test pits) shows that the cohesion of soil ranges from 0.18 to 0.617 ksc and angle of internal friction is between 19.45 to 29.80 degrees. It is suggested that the properties of the soil shear strength decreases when the moisture content changes. The soil shear strength will reach the rate of high decreases in the range of 72.11 % to 98.78 %, 83 % to 91.20 % and 79.6% to 95.6% for residual soil from shale, siltstone and sandstone, respectively.

5. Strength of soil will highly decreases when the moisture content in soil increases. Therefore, the natural soil slope in the study area can be stable when the moisture content in soil level is equal one

but when the moisture content between soil particle increases, strength of soil can be decreased resulting in soil strength decreases.

6. Acknowledgements

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7. References

ASTM., 1995. Annual Book of ASTM Standards, American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

Akkrawintawong, K ., 2006. Landslide Hazard Investigation in Changwat Nan. M.Sc thesis (unpublished), Department of Geology, Faculty of Science, Chulalongkorn University: 200 pp.

Fleming, H.D., 1952. Undrained triaxial compression tests on a decomposed phyllite. In First Australia New Zealand Conf. Soil Mech. And Found. Eng. Australia. pp 112-122.

Hazelton, P. and Murphy, B., 2007. Interpreting Soil Test Results "What Do All The Numbers Mean?" ISBN 978 0 64309 225 9.

Kenney, T.C. and Watson, G.H., 1961. Multiple-Stage Triaxial Test for Determining c' and f' of Saturated soils. In 5th Int. Conf. Soil Mech. Vol.1., pp.191-195.

Kunsuwan, B., 2005. Behaviors of Slope Failures in Chantaburi Watershed Area, Master Thesis, Kasetsart University, Bangkok.

Mairaing, W., Thaijeamaree, N., Kulsuwan, B., 2005. Landslide study in Pecthchaboon and Chantaburi.

Mairaing, W., 2008. Landslide Problems and Warning by Geotechnical Methods. CAFEO26 (26th Conference of the ASEAN Federation of Engineering Organization). Sofitel Centara Grand Hotel, Thailand.

Soralump, S and Thowiwat, W., 2007. Shear Strength - Moisture Behavior of Residual Soils of Landslide Sensitive Rocks Group in Thailand. The Fifteenth National Convention on Civil Engineering (NCCE15), 12-14 May 2010. Ubon Ratchathani, Thailand.

Soralump, S and Thowiwat, W., 2009. Shear Strength Behavior of Residual Soils in Thailand for Supporting Landslide Warning Analysis and Geotechnical Engineering Design. The Fourteenth National Convention on Civil Engineering (NCCE14), 13-15 May 2009. Nakhon Ratchasima, Thailand.

Taylor, D.W., 1950. A triaxial shear investigation on a partially saturated soil. In ASTM. Spec. Tech. Pub. No. 106. pp. 180-191.