ASM Sc. J., 11, Special Issue 3, 2018 for SANREM, 79-85

Effect of Moisture on Engineering Properties of Soil Slopes from Melange in Sandakan Sabah, Malaysia

Baba Musta[1,2*], Afrida Sri Rahayu Karim[1], Hennie Fitria Soehady[1,2], Kyoung Woong Kim[3] and Joon Ha Kim[3]

[1]*Natural Disaster Research Centre (NDRC), Universiti Malaysia Sabah (UMS), Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia*

[2]*International Environmental Research Institute, Gwangju Institute of Science and Technology, 123 Cheomdan-gwagiro, Buk-gu, Gwangju*

A total of five soil samples were collected from mélange weathered material in order to analysis the effect of moisture on engineering properties of the soils. The soil samples were collected along the main road in Sandakan, Sabah. The result of analysis shows that the soil moisture content was in the range of 15.26% to 22.10%. The average liquid limit of soil samples was from 45.1% to 59.8%, while the plasticity indexes were in the range of 23.25% to 33.91%. The plasticity chart plot of soil found that S1 and S5 were classified as low plasticity soil, while S2, S3 and S4 soil were classified as high plasticity. The result shows that the optimum moisture contents ranged from 13.0% to 28.9%, while the maximum dry density is within a range from 1.43Mg/m^3 to 1.82Mg/m^3. The unconfined compression strength indicated that S3 is classified as very soft soil, S1 and S4 soft soil, S2 moderate soft soil and s5 strong soil. Additional of moisture above optimum content in to the soil resulted in lower strength for all soil samples, whereas higher strength value range were observed when the moisture content is reduced below the optimum content. As conclusion, additional moisture contents influenced the engineering properties of soil samples due to its high adsorption of water in clayey soil as identified from the XRD and SEM analysis

Keywords: Soil slope, landslide, melange, rain fall

I. INTRODUCTION

The study area is located in the main road of Sandakan, Sabah, Malaysia which often occurrences of landslides and soil creeping that causing road damages (Figure 1). The soil mostly originated from weathered mélange materials (Figure 2). The mélange consists of mixed rocks including blocks of different ages and origin, commonly embedded in shale matrix (Sanudin & Baba, 2017). The admixture of rocks with varies sizes and varied with matrix of sandstone, mudstone and shale in Sandakan area was reported as Garinono Formation (Collenette, 1966; Hutchison, 2005).

According to Festa *et. al* (2010), mélange has lack of internal continuity of rock layer and contact, therefore this structure contributed to the damage of rock structure. Different soil has different strength, depending on the parent materials and mineral contents. Friction angle of soil influenced by its mineral contents, shape of soil particles, pore ratio, organic materials content and soil grades (Hossain, 2010). Besides of geological factors, this study area has tropical climate which experience high rainfall

*Corresponding author's e-mail: babamus@ums.edu.my

intensity throughout the year. Fine grain soil became low plasticity and slurry when mixed with high percentages of water therefore will trigger the landslide (Johansson & Edeskär, 2014; Jacob & Lambert, 2009). Plasticity nature of clay makes it susceptible to failure due to reduce of soil shear strength. This situation is probably due to the rock and soil type in this area which consists of clayey soils. Most landslides are triggered by hydro climatic events such as prolonged or intensive rain (Syaran *et. al.*, 2014; British Standards 1377, 1990). Determining landslide triggered by accumulated of rainfall method for an early warning and monitoring tool using analytical hierarchy process as an option tool were reported by Wu & Chen (2009). Therefore, understanding the engineering properties of melange soil and variation of its optimum moisture content is vital in order to understand the relationship with the occurrences of landslide and rainfall in this area.

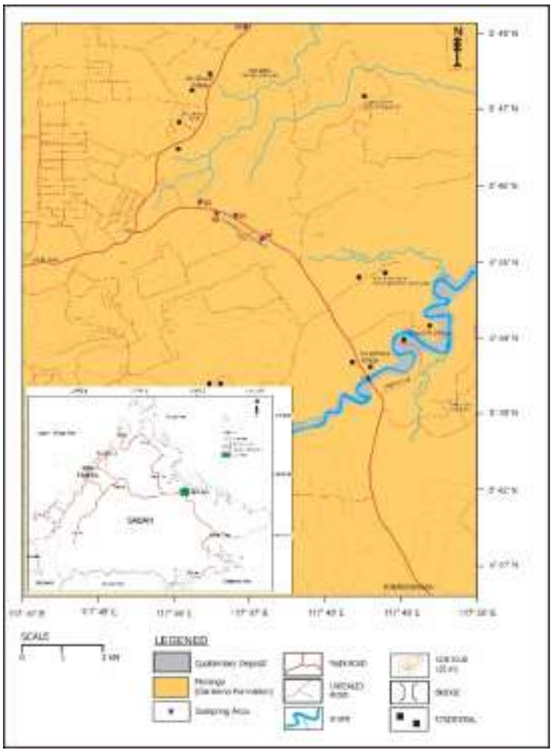


Figure 1. Geological map of the study area in Sandakan, Sabah (Sanudin & Baba, 2007).

(A)

(B)

(C)

(D)

Figure 2. The outcrops showing the occurrences of mass movement of clayey soil originated from mélange in the study area.

II. MATERIALS AND METHODS

Field investigations involved the study of mélange distribution, slope along the main road and sample collection. About five soil samples were collected from the slopes along the main road in the study area (Figure 1). Study of slope distribution and parameters includes the record of slope orientation, angle, length, height, and the type and extent of vegetation of the area. The occurrence of groundwater seepage on the area is also recorded.

The laboratory analysis involved the physico-chemical analysis, engineering properties analysis, and mineral content analysis. The parameters in physico-chemical analysis are natural moisture content, organic content, pH value, particle size distributions and specific gravity of soil. The physico-chemical analysis was followed BS1377 methods (Head, 2008). The Atterberg's limits were analyzed to identify the type of soil plasticity. Engineering properties consist of Proctor test, unconfined compression test (UCT) and permeability test. The percentage of increases and decreases of moisture content in soils were used to identify the effect of moisture (rainfall volume) on the soil's strength value.

III. RESULTS AND DISCUSSION

A. Physico-chemical Properties

Table 1 shows the results of analysis for moisture content, organic matter content, specific gravity, and pH for five soil samples collected from mélange materials in Sandakan, Sabah. Base on the results the soil moisture content was at the range of 15.26% to 22.10%; the soil organic content ranges from 1.10% to 2.32%; the soil specific gravity at the range of 2.57 to 2.61, and the average pH value was from pH 4.80 to pH 7.60. Sample S3 and S4 shows the acidity of soil whereas, S1, S2 and S5 was alkaline. Sample S3 shows the highest moisture content which was 22.10%, while S4 shows the highest soil organic content (2.32%) and highest specific gravity (2.61). The specific gravity tests were conducted to determine the density of each soil sample by calculating the ratio between the mass of dry soil and distilled water.

Table 1. Physico-chemical properties of soil samples

No. Sample	Moisture content Wo (%)	Organic matter content, OM (%)	pH	Specific Gravity SG
S1	16.05	1.11	7.45	2.60
S2	20.75	1.32	7.60	2.58
S3	22.10	2.12	5.25	2.57
S4	16.00	2.32	4.80	2.61
S5	15.26	1.10	7.51	2.58

Table 2 shows the percentage of clay, silt and sand for all five soil samples. Based on the Head (2008) classification, it was found that all soil samples were best classified as clay soil. The uniformity coefficient (Cu) and curvature coefficient (Cc) results indicated the S1 was uniform and well graded; while the rest were poorly graded.

Table 2. Grain size distributions of soil samples

Sample	Percentages of Grain size (%)			Soil Classification	Grade
	Clay	*Silt*	*Sand*		
S1	34.58	41.59	23.83	Clay	Well sorted
S2	40.49	44.25	15.26	Clay	Poorly sorted
S3	36.83	33.63	29.54	Clay	Poorly sorted
S4	41.60	34.00	24.40	Clay	Poorly sorted
S5	34.91	49.83	15.26	Clay	Poorly sorted

The result of Atterberg's limits tests for three soil samples are given in Table 3. Atterberg's limits consist of plastic limit test, liquid limit test, soil plasticity index and linear shrinkage. Soil conditions can be divided into four phases, namely solid, semi-solid, plastic and liquid (Head, 2008). Based on the analysis, average liquid limit of soil samples were from 45.1% to 59.8%. Average plastic limit ranged from 21.48% to 33.49%, while the plasticity indexes were in the range of 23.25% to 33.91%. The plasticity chart plot of soil found that S1 and S5 were classified as low plasticity soil, while S2, S3 and S4 soil were classified as high plasticity (Figure 3). Based on the clay activity analysis it was found that all soil samples are classified as inactive clay except for S2 soil which classified as normal clay. The analysis results showed the linear shrinkage percentage was at the range of 12.14% to 17.14%.

Table 3. Results of the Atterberg's Limit of soil samples

Sample	Average liquid Alimit, L_L (%)	Average plastic limit, P_L (%)	Plasticity index, I_P (%)	Linear shrinkage, L_S (%)
S1	45.1	21.85	23.25	12.14
S2	56.4	22.49	33.91	13.57
S3	59.8	33.49	26.31	17.14
S4	56.2	27.84	28.36	15.00
S5	46.4	21.48	24.92	12.86

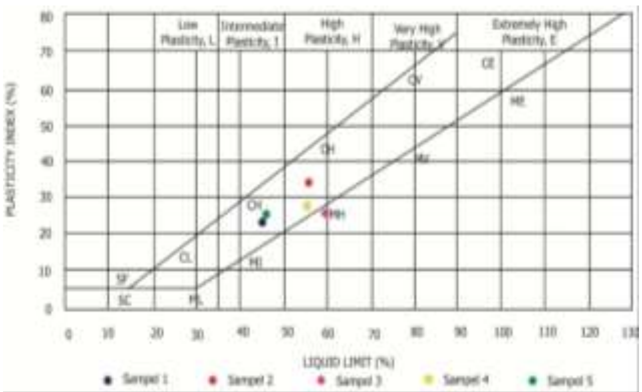


Figure 3. Plasticity chart of soil samples.

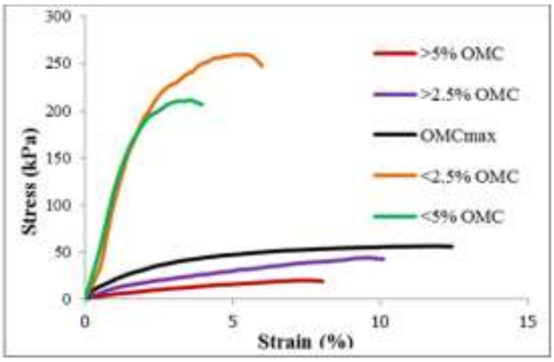
B. Engineering Properties

The engineering properties consist of compaction test, unconfined compression test, and permeability test. Proctor compaction test were conducted to determine the maximum dry density and optimum moisture content of the soil samples. This test is intended to increase the density of the soil samples by reducing the volume of the air space between the soil particles through compaction methods. Table 4 shows the optimum soil moisture content, maximum dry density. The result shows that the optimum moisture contents ranged from 13.0% to 28.9%, while the maximum dry density is within a range from 1.43 Mg/m3 to 1.82 Mg/m3.

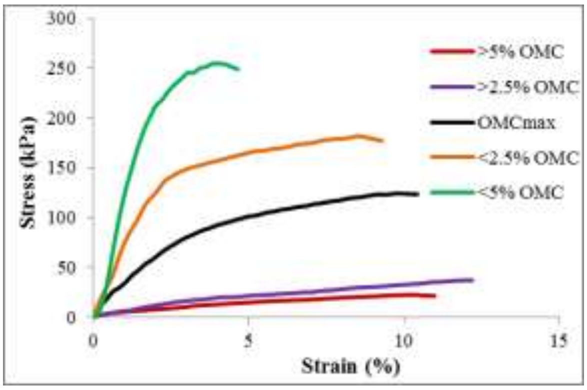
Table 4. Engineering properties of soil samples

Samples	Optimum Moisture content, Wopt (%)	Maximum Dry density, p_D (Mg/m^3)	Unconfined compression test (kPa)	Permea-bility value, k (m/s)
S1	14.0	1.82	56.70	5.12×10^{-8}
S2	14.0	1.76	124.3	3.09×10^{-9}
S3	28.5	1.43	16.87	2.66×10^{-8}
S4	25.5	1.51	54.08	2.02×10^{-9}
S5	13.0	1.78	203.57	1.03×10^{-8}

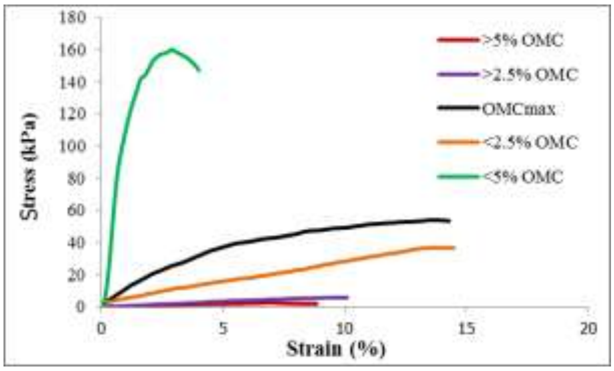
Unconfined compression test was conducted to determine the stress strength of the soil samples when subjected to compressive forces. Stress resistance strength is the maximum power per soil area that can be produced by a soil sample to prevent failure or slide along its plane. The unconfined compressive strength classifications were based on Terzaghi *et. al* (1996) classification. The result of the unconfined compression test shows that S3 is classified as very soft soil, S1 and S4 soft soil, S2 moderate soft soil and S5 strong soil (Table 4). The permeability tests were conducted to determine the permeability of the soil to drain water between its pore spaces. The result shows that the permeability of all soil samples is best classified as very low permeability (Terzaghi *et. al.*, 1996). UCT test with different moisture content (>5%, >2.5%, <5% and <2.5% OMC) also conducted on all five soil samples. The results of the test were shown on Figure 3. The result indicated that less moisture content from the optimum value will increase the strength of the soil, whereas the increase of moisture content be able to reduce the strength of the soil. The result obtained from the analysis also shows that the possibility of failure of mélange slope occurred during heavy rain. At the stage the soil particle not be able to maintain the slope stability due to the increasing of the soil moisture above the optimum moisture content.



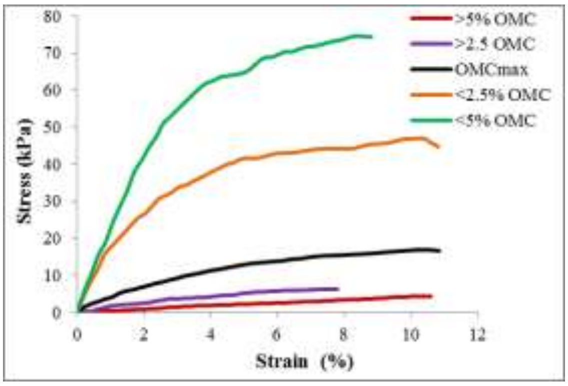
S1



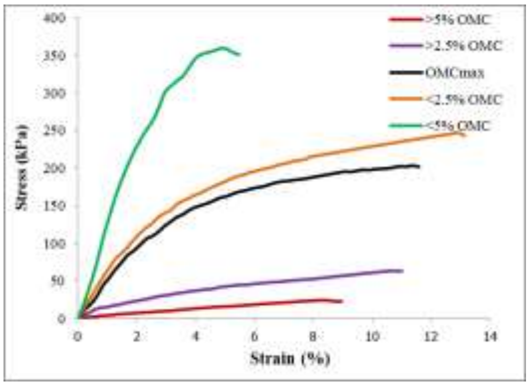
S2



S4



S3



S5

Figure 3. UCT test with different moisture content of all five soil samples

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IV. SUMMARY

The physico-chemical properties of soil samples from mélange shows that the moisture content, organic matter and specific gravity were 15.26% - 22.10%; 1.10% - 2.32%; and 2.57 - 2.61 respectively. The pH value was varies from acidic (4.80) to alkaline (7.60). The average liquid limit was 45.1% - 59.8%, while the plasticity index was 23.25% to 33.91%. The plasticity chart of soil shows that S1 and S5 were classified as low plasticity soil, while S2, S3 and S4 soil were classified as high plasticity.

The result of engineering properties shows that the optimum moisture contents ranged from 13.0% to 28.9%, while the maximum dry density is within a range from 1.43Mg/m^3 to 1.82Mg/m^3. The unconfined compression strength indicated that S3 is classified as very soft soil, S1 and S4 is soft soil, S2 is moderate soft soil and S5 is strong soil. The permeability of all soil samples is classified as very low permeability.

The additional different percentages of water into the maximum dry density soil were performed to determine the influence of rainfall on landslide. The result of unconfined compression test

indicated that less moisture content from the optimum value will increase the strength of the soil, whereas the increase of moisture content able to reduce the strength of the soil. The addition 2.5% and 5.0% of moisture for clayey soil shows immediate decreased of the soil strength. At this stage the soil particle not be able to maintain the slope stability due to the increasing of the soil moisture above the optimum moisture content. As a conclusion the mélange soil slopes has potential to be failure due to the heavy rainfall.

V. ACKNOWLEDGEMENT

This study was supported by the Ministry of Science and Technology in South Korea through the International Environmental Research Institute (IERI), Gwangju Institute of Science and Technology, Gwangju, Korea. All laboratory works have been done in the Faculty of Science and Natural Resources, Universiti Malaysia Sabah, Kota Kinabalu, Sabah, Malaysia.

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