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Engineering Properties and Mineralogical Identification of Soil from Melange in Sandakan Sabah, Malaysia

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***Abstract*— A total of five soil samples were collected from melange weathered material in order to analysis the engineering properties and mineralogical identification 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 soil organic content range from 1.10% to 2.32%, and the soil specific gravity in the range of 2.57 to 2.61. Sample S3 and S4 shows the acidity of soil whereas, S1, S2 and S5 was alkaline. The average liquid limit of soil samples were 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 samples were classified as low plasticity soil, while S2, S3 and S4 samples were classified as high plasticity. The result shows that the optimum moisture contents range from 13.0% to 28.9%, while the maximum dry density was 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. The permeability of all soil samples is best classified as very low permeability. The mineralogical identification using XRD and SEM proved the appearance of clay minerals and quartz as a main mineral content of all soil samples.**

***Keywords*— soil, melange, engineering properties, mineralogy**

I. Introduction

The study area is located in the main road of Sandakan, Sabah, Malaysia which often occurrences of landslides and soil creep that cause road damaged. The soil mostly originated from weathered mélange materials. The melange consists of mixed rocks including blocks of different ages and origin, commonly embedded in shale matrix (1). The admixture of rocks with varies sizes and varied with matrix of sandstone, mudstone shale and clay in Sandakan area was reported as Garinono Formation or Broken Formation (2) and (3).

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According to (4) 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 its parent material and mineral contents. Friction strength of soil influenced by its mineral contents, shape of soil particles, pore ratio, organic materials content and soil grades (5). Besides of geological factors, this study area has tropical climate which experience high rainfall intensity throughout the year. Fine grain soil became low plasticity and slurry when mixed with high percentages of water therefore will trigger the landslide (6) and (7). 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 (8) and (9). Understanding the engineering properties and main type of minerals is vital in order to understand the relationship with the occurrences of landslide in this area.

II. Material and Methodology

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. 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 were followed BS1377 methods (10). The Atterberg's limits were analyzed to identify the type of soil plasticity. Engineering properties consist of Proctor test, and unconfined compression test (UCT) and permeability test. The microstructures of the soil sample were observed using SEM analysis and the identification of soil minerals were analyzed using XRD. The identification of minerals from X-Ray Diffractograms was based on Moore and Reynolds (11).

III. Result and Discussions

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 table the soil moisture content was at the range of 15.26% to 22.10%; the soil organic content range 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 I. PHYSICO-CHEMICAL PROPERTIES OF SOILS

No. Sample	Moisture content Wo (%)	Soil 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 II shows the percentage of clay, silt and sand for all five soil samples. . Based on the Head (12) 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 II. GRAIN SIZE DISTRIBUTIONS OF SOILS

Sample	Percentages of Grain size (%)			Soil Classi-fication	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 five soil samples are given in Table III. 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 (12).

TABLE III. RESULTS OF THE ATTERBERG'S LIMIT

Sample	Average liquid limit, 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

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 1). 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%.

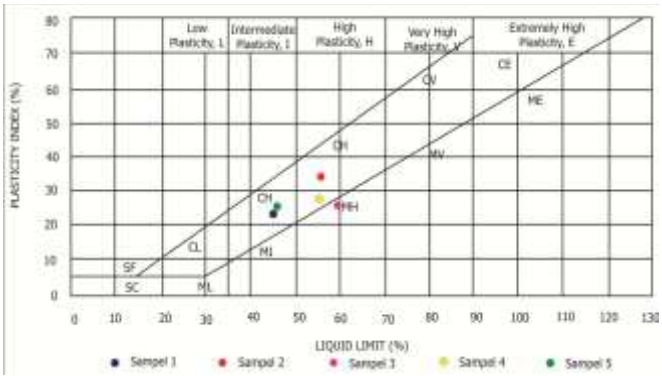

Figure 1. Plasticity chart of soil samples.

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 IV shows the optimum 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 1.43Mg/m^3 to 1.82Mg/m^3.

TABLE IV. ENGINEERING PROPERTIES OF SOILS

Sample	Optimum Moisture content, Woptω_o (%)	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 x 10^{-8}
S2	14.0	1.76	124.3	3.09 x 10^{-9}
S3	28.5	1.43	16.87	2.66 x 10^{-8}
S4	25.5	1.51	54.08	2.02 x 10^{-9}
S5	13.0	1.78	203.57	1.03 x 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 (13) 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 IV). 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 (13).

C. *Mineralogical Study*

Analysis of mineral content in the soil samples was based on X-ray diffraction (XRD) analysis and scanning electron microscope (SEM). The result of XRD analysis shows that the main mineral content in the soil samples are quartz (Q), kaolinite (K) and ilite (I). The micro morphology and micro structure of soil from SEM images show the appearance of kaolinite layered, while illite which has a finer grain size than kaolinite also were observed. The X-ray diffractograms and electron microscopic images for samples S1, S2, S3, S4 and S5 are given in Figure 1, Figure 2, Figure 3, Figure 4 and Figure 5 respectively.

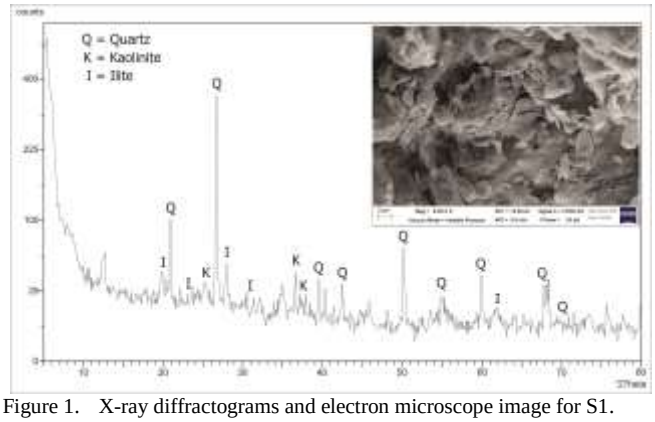

Figure 1. X-ray diffractograms and electron microscope image for S1.

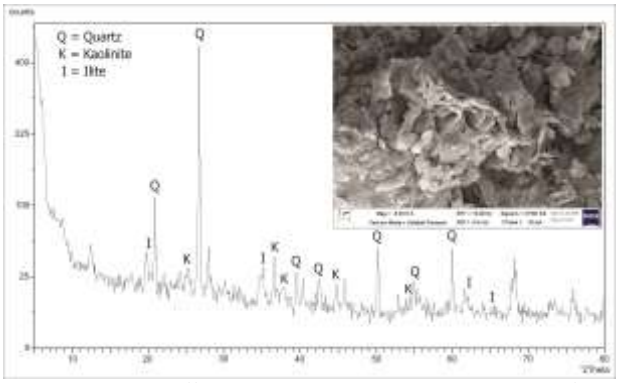

Figure 2. X-ray diffractograms and electron microscope image for S2.

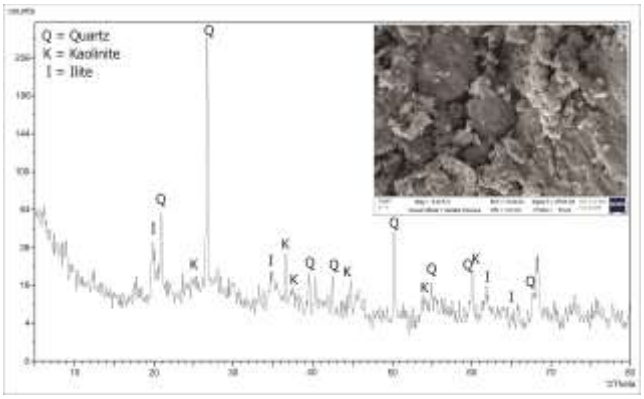

Figure 3. X-ray diffractograms and electron microscope image for S3.

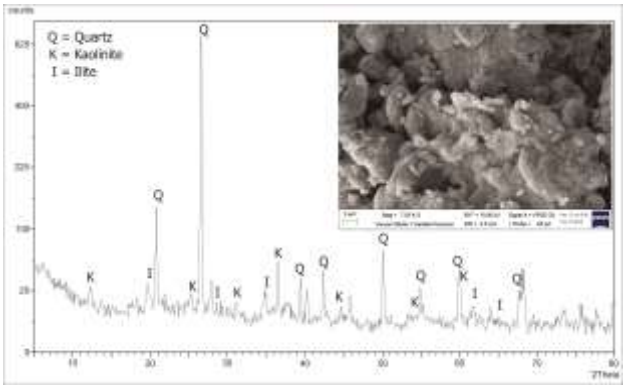

Figure 4. X-ray diffractograms and electron microscope image for S4.

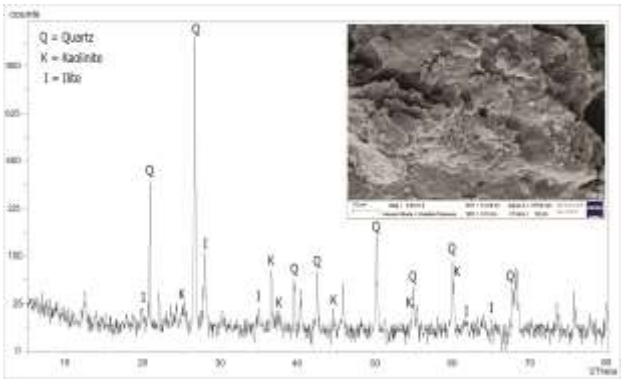

Figure 5. X-ray diffractograms and electron microscope image for S5

IV. Conclusions

i. The 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.

ii. 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.

iii. The mineralogical identification using XRD and SEM proved the appearance of main mineral content of all soil is kaolinite, illite and quartz.

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