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Geotechnical Characterization in Hilly Area of Kundasang, Sabah, Malaysia

Mohd. Radzif Taharin[1], Rodeano Roslee[2, 3], and Amaludin, A. E.[4]

[1]*Civil Engineering Programme, Faculty of Engineering, Universiti Malaysia Sabah, 88400 Kota Kinabalu, Sabah, Malaysia*

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

[3]*Faculty of Science and Natural Resources (FSSA), University Malaysia Sabah (UMS), Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia*

[4]*Civil Engineering Programme, Faculty of Engineering, Universiti Malaysia Sabah, 88400 Kota Kinabalu, Sabah, Malaysia*

Geotechnical Characterization is an approach that derives from the soil investigation report. Often, the soil investigation report would provide the information regarding the proposed development area, or the area which involved in the remedial work. And in the soil investigation reports, the most important values were arranged in the separated sections. With geotechnical characterization, all the important data will be summarized and compiled in the convenient way to describe the soil condition of the area. This paper provides an overview of the geotechnical characterization in this particular area which could be utilized to solve existing issues in the construction industry. The scope of this study is confined to several aspects, namely soil types in the boreholes according to the USCS, liquid limit, plasticity index, soil cohesion, angle of internal frictions, and soil plasticity. Among the many applications of this approach includes slope stability, soil shear strength and foundation design. As a result of this study, it was found that the geotechnical characterization application could provide different view of soil condition, despite of the early assumption based on the borehole report. With this approach, the determination of the soil condition could provide the information and insight, which related to the prevention of landslide and soil mass movement.

Keywords: Geotechnical Characterization, Soil Types, Plasticity Index, Liquid Limit, Soil Plasticity

I. INTRODUCTION

Kundasang, is a place where the majestic Mount Kinabalu is situated. With the height of 4095.2 metres, Mount Kinabalu prevails as the highest peak in southeast Asia. As a part of the Crocker Range area, located in the district of Ranau, Sabah, this mountainous area is only 90km from Kota Kinabalu, Sabah and becoming a very popular tourist attraction. Other than popular as tourist attraction, Kundasang is also known for agricultural and dairy products. Basically, the activities that generate the economy in this area are based on the

*Corresponding author's e-mail:

agriculture and tourism. The location of Ranau district could be seen from the Figure 1 below.

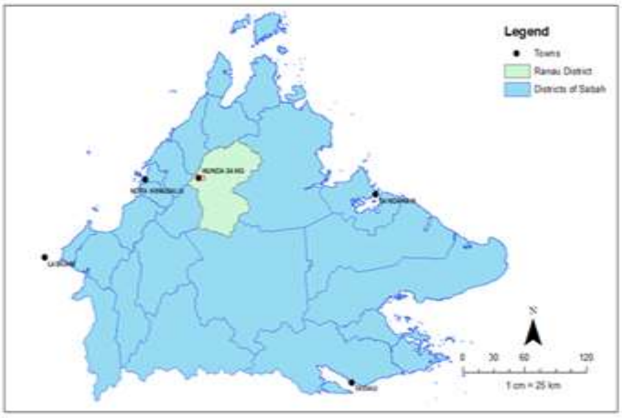

Figure 1. Location of Kundasang, Sabah

Despite blessed with a beautiful panoramic view and cool climate (Figure 2), Kundasang area is exposed to the natural disasters, such as soil mass movement, which includes landslide. High frequency of these natural disasters, especially at the road and residences area, has causing inconvenience to the community and the road users. Matters become worse since the transportation road is the main road which connecting West Coast to East Coast of Sabah (Simon *et al.,* 2015). For residences, these natural disasters will cause disruption to daily activities due to the utility damages such as water supply, electrical power, and telecommunications line. These types of damages are taking quite sometimes to restored to the normal conditions.

Figure 2. Panoramic view of Kundasang, Sabah

II. GEOTECHNICAL CHARACTERIZATION PROCESS

Geotechnical characterization is the process to characterize the soil properties, according to the parameter needed for the research. The expected results for these objectives are listed as below:

1. The values of cohesion (c) and angle of internal friction (ϕ) for every borehole.
2. The descriptive statistics of c, ϕ, Plasticity Index (PI) and Liquid Limit (LL).
3. The soil stratigraphy from ground level to the borehole depth, according to the USCS BS1377.

These values of c and ϕ could only considered up to 10 metres depth due to the insufficient of the data beyond this depth. Plasticity data such as plasticity index (PI) and liquid limit (LL) values would also be included in the results to identify the types of soil plasticity in the study area. Every involved parameters' value such as c, ϕ, plasticity index (PI) and liquid limit (LL) will be listed according to the boreholes, in the tabulated form. The soil stratigraphy would also be part of the results, and provided according to the boreholes depth and the type of soil. The diagram from the ground level until the borehole depth would be provided according to the obtained data.

Descriptive statistics, which purpose is to summarize data, will be applied to determine the distribution of the involved parameters. By applying descriptive statistics, the measures of central tendency would provide information about the parameters' characteristics, such as median, mean, maximum value and minimum value. The measures of dispersion such as variance and standard deviation could provide information about the spread of parameters' value (Altman and Bland, 1996). For PI and LL values, should there be several values in a borehole within the 10 metres depth, the mean will be used to represent those values. The PI and LL values will be mapped to the soil plasticity chart in BS5930-1999 to determine the type of soil according to the mentioned chart, in the study area.

III. STUDY AREA AND BOREHOLES LOCATION

Borelog reports were obtained from JKR, including the drawings of the area, which contained the borehole locations. Geotechnical characterizations were proceed by arranging the data according to the borehole. The field visits were made to ensure that the boreholes locations are identical between drawings and the site. For this research, data from two borelog reports, namely KM 93.3 Kota Kinabalu-Ranau Road and KM 94.1 Kota Kinabalu-Ranau Road, will be used. The combination of both reports consists of 70 boreholes, which 54 of them are from KM 93.3 Kota Kinabalu-Ranau Road and 16 of them are from KM 94.1 Kota Kinabalu-Ranau Road.

The field visit has been done in order to determine the boreholes location of the study area, based on the boreholes drawing given by JKR. The coordinates of the boreholes need to be synchronized to ensure that the actual borehole locations are aligned with the given coordinates. The given coordinates were in the form of northing and easting, while the latest approach on the coordinates are using Global Positioning System (GPS). Through field visits, the differences have been identified and been sorted out. The conversion of the coordinates from the northing easting based to the GPS based has been successfully delivered, and the actual boreholes location has been identified.

After adjustments, all boreholes location are displayed in the Figure 3. For KM93.3 Kota Kinabalu-Ranau Road, there are 54 boreholes and were indicated by the red points, while for KM94.1 Kota Kinabalu-Ranau Road, there are 16 boreholes and were indicated by blue points.

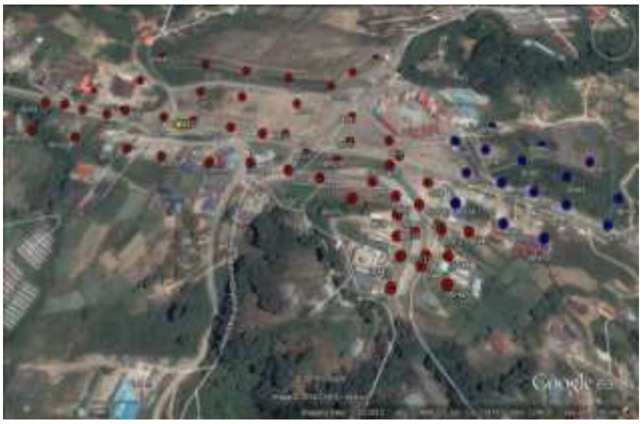

Figure 3. Boreholes location of the study area

IV. EXPERIMENTAL RESULT

From Table 1, the minimum and maximum value for cohesion are 0 kN/m^2 and 13.19 kN/m^2. For the angle of internal friction, minimum and maximum value are 21.61^0 and 35.31^0. Most boreholes are showing low cohesion values with high angle of internal friction values or vice versa.

There are certain boreholes containing high values of cohesion and angle of internal friction such as BH1, BH7, BH20, BH14, BH33, and BH34. While certain boreholes containing low values of cohesion and angle of internal friction such as BH26, BH39, BH40, BH41, and BH63. Liquid Limit (LL) and Plasticity Index (PI) for this area are also provided, with minimum value of 28.5% and maximum value of 42.67% for LL, and minimum value of 10% and maximum value of 23.5% for PI respectively.

From Table 1 also, the values such as, median, variance and standard deviation for every parameter involved are shown. The mean of cohesion, angle of internal friction, LL and PI are 5.70 kN/m^2, 28.90^0, 33.75% and 17.28% respectively. The variance of all

Table 1. Descriptive statistics of soil characterization for Borehole 1 to Borehole 70

	c (kN/m^2)	ϕ (^{0})	LIQUID LIMIT (%)	PLASTICITY INDEX (%)
Minimum	0	21.61	28.5	10
Median	5.18	29.33	33.25	17
Maximum	13.19	35.31	42.67	23.5
Mean	5.70	28.90	33.75	17.28
Variance	8.76	9.60	11.626	9.109
Standard Deviation	2.96	3.10	3.410	3.018
Coefficient of Variance	0.519	0.107	0.101	0.175

parameters are 8.76, 9.6, 11.626 and 9.109. While the standard deviation are 2.96, 3.10, 3.410 and 3.018. Values for coefficient of variance for all parameters are less than one, which showing the dispersion of data is good and well distributed.

The soil stratigraphy of the study area are shown in the Figure 4 to Figure 8 below. The types of soil in this approach are classified into four types of soil according to the USCS, which are clay, silt, sand and gravel. The soil stratigraphy will be displayed from the ground level towards the borehole depth for each borehole in the study area. Each borehole would have different depth. The soil stratigraphy would also indicate the type of soil that found the most in the boreholes of the study area. The findings of the soil stratigraphy will be compared to the soil plasticity chart, to find the similarity between these two approaches.

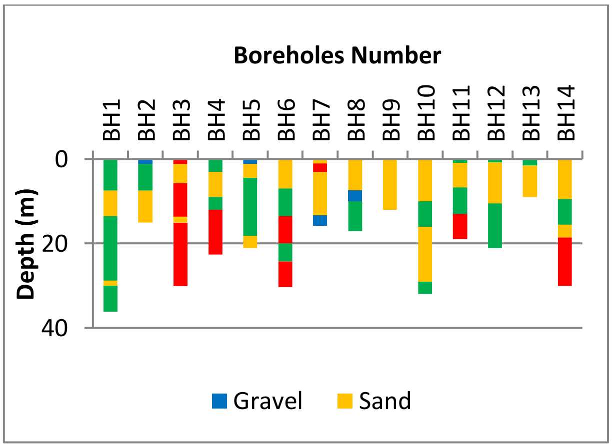

Figure 4. Soil types according to the boreholes depth from BH1 to BH14

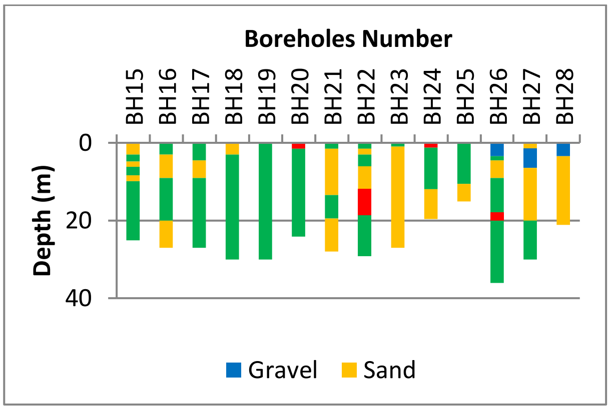

Figure 5. Soil types according to the boreholes depth from BH15 to BH28

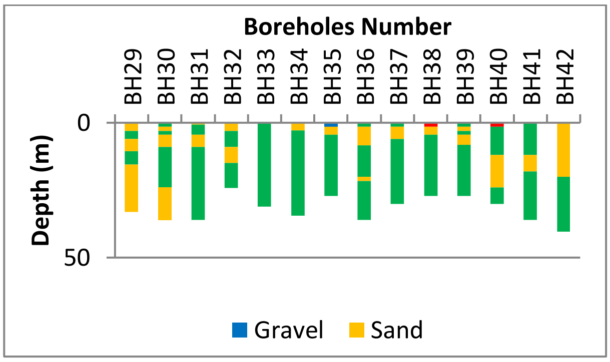

Figure 6. Soil types according to the boreholes depth from BH29 to BH42

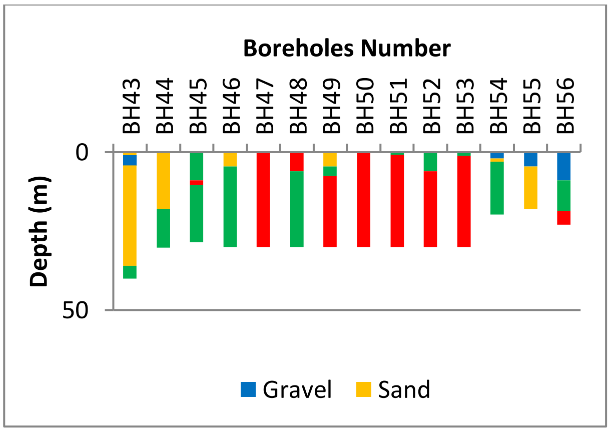

Figure 7. Soil types according to the boreholes depth from BH43 to BH56

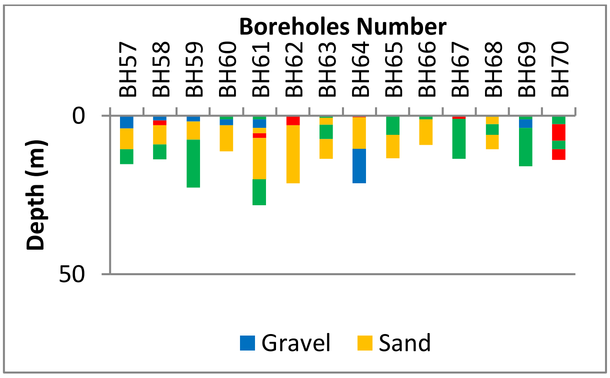

Figure 8. Soil types according to the boreholes depth from BH57 to BH70

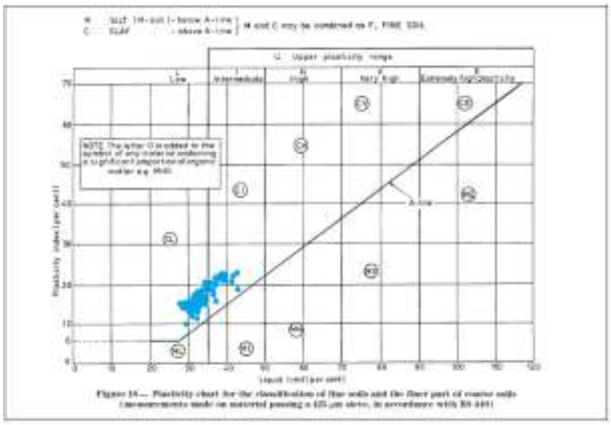

Figure 9. Soil plasticity for the study location (blue points) by using Plasticity Chart (Source: BS5930-1999)

The values of LL and PI for the study area would be mapped to the soil plasticity chart from BS5930:1999 (Figure 9), indicated by the blue dots. Out boreholes, 47 boreholes are categorized as clay with low plasticity (CL), 21 boreholes are categorized as clay with intermediate plasticity (CI), and two boreholes are non-plastic soil (Table 2). Based on this numbers, the clay with low plasticity dominated about 67% of this area, compared with the clay

Table 2. Type of soils according to the soil plasticity chart

Non-Plastic	**Clay with Low Plasticity (CL)**	**Clay with Intermediate Plasticity (CI)**
BH8, BH9	BH1, BH2, BH3, BH4, BH5, BH6, BH7, BH8, BH9, BH10, BH11, BH12, BH13, BH14, BH16, BH17, BH18, BH22, BH23, BH24, BH27, BH28, BH31, BH36, BH38, BH41, BH42, BH43, BH44, BH45, BH46, BH47, BH48, BH49, BH52, BH53, BH54, BH56, BH57, BH58, BH59, BH60, BH63, BH65, BH66, BH67, BH68, BH69, BH70.	BH15, BH19, BH20, BH21, BH25, BH26, BH29, BH30, BH32, BH33, BH34, BH35, BH37, BH39, BH40, BH50, BH51, BH55, BH61, BH62, BH64.

From Figure 4 to 8 above, it could be seen that the silt is dominating most of the study area, followed by sand, clay and gravel. Clay were dominating few boreholes but significantly, such as BH47, BH49, BH50, BH51, BH52, BH53 and BH70. Despite these boreholes were dominated by clay, only BH50 and BH51 were classified as clay with intermediate plasticity (CI). The clay presence is still visible despite of the silt domination. These soils is showing the character of clay with low plasticity (CL) and clay with intermediate plasticity (CI), instead of silt with low plasticity (ML) or silt with intermediated plasticity, according to the BS5930-1999.

The soil profiles could be used as an approach to determine the type of soil in the borehole, which representing the study area. The prediction of the strength of this area could be done based on the provided information. However, the additional data such as soil plasticity is essential to ensure the accuracy of the soil type. This is due to the soil mixture, whereby the type of soil such as clay and silt, or clay and sand might mixed up, and the changes of the soil properties might occurred. Once the soil properties have been changed, the dominance of the soil type is playing an important role to determine the soil properties. Through soil plasticity, the type of soil could be determined despite differences in the soil stratigraphy.

V. CONCLUSION

This study shows that through geotechnical characterization, the soil property could be determined accurately, which is not depending solely in soil stratigraphy, but through the utilization of the soil plasticity chart as well. Despite of the dominance of the silt and sand, the view through the soil plasticity chart is showing the existence of clay properties, but less dominant and being dominated by different type of soil property.

This study shows that significant content of clay with does not necessarily contribute to the landslide. And the resistance of the soil for this area might be due to the high angle of internal frictions (Anchuela *et al.,* 2015). The uniformity of the soil, might changed due to the frequent landslides occurence, and it might contribute to the low cohesion even if the percentage of clay is significant (Zhao, Zhang, Xu, & Chang, 2013). The main reason Kundasang was stable during most of the times due to the presence of the sand in high significant percentage, with high angle of internal frictions and low cohesion, but it is prone to have landslide during long hours of rain (Sorbino, Nicotera, & Marco Valero, 2012).

VI. ACKNOWLEDGMENT

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