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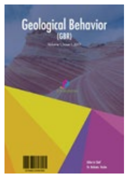

Comparison of Cohesion (c'), and Angle of Internal Friction (Φ') Distribution in Highland Area of Kundasang by using Ordinary Kriging and Simple Kriging.

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ABSTRACT

The objective of the research is to determine the distribution of cohesion (c'), and angle of internal friction (Φ') values for the highland area of Kundasang, Sabah by using kriging. A set of data from two adjacent site in Kundasang were collected from the site investigation report. There are three main stages in determining these parameters. The first stage is to use ordinary kriging methods to determine the modelling for these parameters. The second stage is to compare the results from ordinary kriging methods to simple kriging methods. The third stage is to produce the mapping for these parameters in the site, which could be used for slope stability and foundation design.

1. INTRODUCTION

Sabah is located at the north of Borneo Island, East Malaysia. The area of the Sabah state is 73,620 km2. Kundasang is located at the toe of the Mount of Kinabalu, which is the highest peak in South East Asia, and part of the Crocker Range, and also the connecting road between west coast and east coast of Sabah (Figure 1). Due to its popularity as a tourist attraction area, the development of holiday resorts has been very rapid in Kundasang area. However, due to the soil mass movement which includes landslides, there are lots of property and infrastructure damages such as houses, buildings and roads.

This study aims to determine the range of c' and Φ' according to the studied area, which could be useful for the geotechnical engineering purposes such as slope stability calculation and design the suitable foundation. With available data, ordinary kriging will be applied to produce the mapping, and simple kriging will be a method for comparison of how effective ordinary kriging as a statistical model to predict these parameters' distribution. According to Ahmad et al., (2005), high cohesion value is highly related to high clay percentage. However, this study would proceed without the soil type.

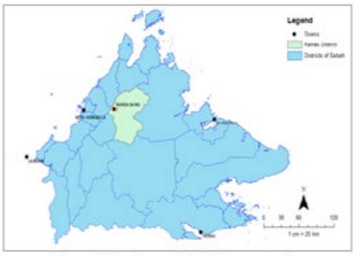

Figure 1: Study area (Kundasang town)
(Source: Ayog, 2015)

2. METHODOLOGY

Popular as a tourist attraction, Kundasang is also connecting the west coast and the east coast of Sabah via transportation road. Furthermore, there are communities who reside in this area. Small town, schools, and other facilities and infrastructures are complete here. Despite of having all these, Kundasang is quite popular for landslide occurrence. Within these decades, there are lots of landslide occurrences alone in Kundasang area. And these landslides are affecting the transportation road and residential area, which causing inconvenience for road users and community, who resides there.

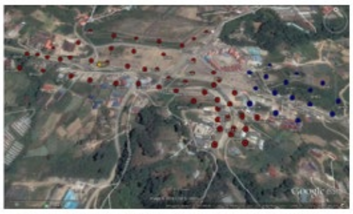

Figure 2: The study area with the boreholes location.
(Source: Google Earth, 2015)

Within these five years, there are five landslides occurrence in Kundasang, and these landslides took place after long heavy rain. Each landslide occurred in 2010 and 2011, while in 2013, there are two landslides and one more in 2014. Due to the high frequency of landslides occurrence, Kundasang area is the most suitable area to be chosen as a study area for landslide.

Different area would provide different type of soil. Due to these criteria, different approach is needed to determine which area is prone to the landslides by determining the range of c' and Φ' values (Cho, 2010).
In order to determine the range of the c' and Φ' in this area, all the values obtained from the borelog reports need to be compiled according to the borehole locations. These compiled data will be interpolated by using kriging to determine the range. Kriging is a geostatistical method, which could predict the properties in the spatial condition. Previously, the popular interpolation method used was Inverse Distance Weightage (IDW). However, due to the uneven topography and terrain condition, kriging method is more suitable to be implemented, with much reduced error (Dai et al, 2014).

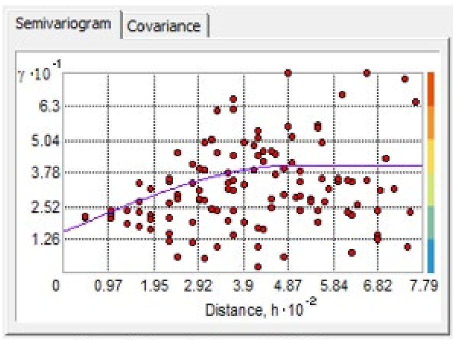

Figure 3: Semivariogram for kriging
(Source: ArcGIS, 2010).

Kriging method has been used in a wide area of study. Woojin et al (2011) showed that the kriging method could provide the settlement estimation in the reclaimed area for development purpose in Seoul. Pokhrel et al (2012) used kriging to estimate the liquefaction potential of alluvium soil in Saitama City, Japan. Kriging is also being used by Gong et al (2013) to determine groundwater with arsenic content in Texas.

In kriging, before mapping can be produced, semivariogram need to be determined, together with the sill, range and nugget. This is due to the fact that this geostatistical method would determine the average value for the search area and with the minimum value of error (Figure 3).

Both parameters c' and Φ' will go through this procedure. There are four types of semivariogram, which are spherical, exponential, circular, and gaussian. The errors will be compared (Root Mean Square Error, Average Standard Error, Mean Standardized Error, and Root Mean Square Standardized Error) and the best model of semivariogram with the lowest error will be selected and compared to the simple kriging semivariogram.

The differences between ordinary kriging and simple kriging, is the mean (μ) in ordinary kriging is unknown, while mean (μ) in simple kriging is known. By comparing the errors between both semivariogram, the effectiveness of the ordinary kriging as prediction tools can be determined.

3. RESULTS AND DISCUSSION

Table 1 is showing the descriptive statistics summary of 70 boreholes in Kundasang Town for this study, which focused on the cohesion (c') and angle of internal friction (Φ'). The data in the Table 1 is showing the range of the c' is between 0 to 13.19kN/m2, with the average or mean of 5.70 kN/m2. While the range of Φ' is between 21.61^0 and 35.31^0, with the average or mean value is 29.33^0.

From the analysis of the cohesion (c') data, the semivariogram for cohesion has been obtained by using ordinary kriging (Table 2) and simple kriging (Table 3). From Table 2, the best model for semivariogram is the Circular model. From Table 3, the best model for semivariogram is the Exponential model. By comparing both of these two model, it shown that the error between known and unknown mean is approximately 0.3% (RMSE)

Table 1: Descriptive statistics of soil parameters for 70 boreholes in Kundasang Town.

	c'	Φ'
Minimum	0	21.61
Median	5.18	29.33
Maximum	13.19	35.31
Mean	5.70	28.90
Variance	8.76	9.60
Standard Deviation	2.96	3.10
Coefficient of Variance	0.5191	0.1072

Table 2: Semivariogram for cohesion (c') by using Ordinary Kriging.

Error and Type of semivariogram	RMSE	ASE	MSE	RMSSE
Spherical	2.916	2.953	-0.008967	0.9884
Exponential	2.914	2.955	-0.0006858	0.9867
Circular	2.910	2.953	-0.01124	0.9864
Gaussian	2.921	2.955	-0.00807	0.9895

Table 3: Semivariogram for cohesion (c') by using Simple Kriging.

Error and Type of semivariogram	RMSE	ASE	MSE	RMSSE
Spherical	2.914	2.944	0.002596	0.9903
Exponential	2.913	2.953	-0.000051	0.9880
Circular	2.917	2.943	0.005034	0.9917
Gaussian	2.920	2.946	-0.002758	0.9916

From the analysis of the angle of internal friction (Φ') data, the semivariogram for angle of internal friction has been obtained by using ordinary kriging (Table 4) and simple kriging (Table 5). From Table 4 and 5, the best model for semivariogram are both the Gaussian model. By comparing both of these two model, it shown that the error between known and unknown mean is approximately 0.8% (RMSE).

Table 4: Semivariogram for angle of internal friction (Φ') by using Ordinary Kriging.

Error and Type of semivariogram	RMSE	ASE	MSE	RMSSE
Spherical	3.076	2.973	0.0004437	1.033
Exponential	3.085	2.982	0.0001804	1.036
Circular	3.075	2.971	0.000491	1.035
Gaussian	3.065	2.973	0.000347	1.029

Table 5: Semivariogram for angle of internal friction (Φ') by using Simple Kriging.

Error and Type of semivariogram	RMSE	ASE	MSE	RMSSE
Spherical	3.068	2.970	-0.000400	1.033
Exponential	3.078	2.978	-0.000607	1.035
Circular	3.067	2.968	0.000138	1.033
Gaussian	3.057	2.970	0.000102	1.028

After the best semivariogram model have been selected, the mapping will be developed, by using ArcGIS software, and it will be layered on the Google Earth mapping to relate the mapping to the actual condition on site.

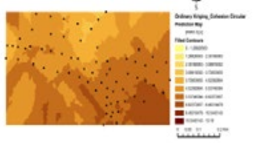

Figure 4: Cohesion distribution mapping by using Ordinary Kriging

From cohesion mapping in Figure 4, it could be seen that the high cohesion value, which represented by darker color, located at the southeast of this area, and the low cohesion value is located at the north of this area.

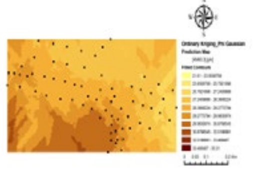

Figure 5: Angle of internal friction distribution mapping by using Ordinary Kriging

From angle of internal friction mapping in Figure 5, it could be seen that the high Φ'value, which represented by darker color, located at the south of this area, and the low Φ' value is located at the east and north of this area.

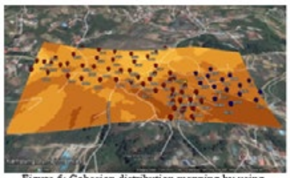

Figure 6: Cohesion distribution mapping by using Ordinary Kriging layered on Google Earth

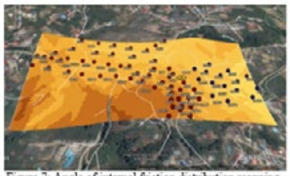

Figure 7: Angle of internal friction distribution mapping by using Ordinary Kriging layered on Google Earth

From this result, there are some interesting findings that could be observed. The low c' and Φ' values could be found in the same place, and the high c' and Φ' values could also be found in the same place. Usually, the low c' values exist with the high Φ' or vice versa, which show the existence of cohesive or non-cohesive soils (Das, 2001).

In this study, it could be seen that, there are differences from this perception, where the low c' values and high Φ' values does not necessarily representing the non-cohesive soils, and the high c' values and the low Φ' values does not necessary associated with cohesive soils (Abedini et al, 2012).

4. CONCLUSION

The research purpose is to use ordinary kriging to provide the values of the important soil parameter in the form of distribution mapping as a guide for the professional who involved in the designing, constructing and developing the area, and for the researchers as well. And the predicted values is showing promising values, which errors is predicted at 0.3 to 0.8%.

By using this method also, it shows that there is a statistical methods, which could be used to predict the distribution of soil parameters. Engineers and researchers would benefit from this research in determining which areas need to be given priority for the risk, which area is need to be avoid, and which area is need the remedial works in the future.

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