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Risk assessment at open dumping area using Monte Carlo simulation

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Abstract. Open dumping area has a potential hazard such as the settlement of the dumping sites, the release of hazardous gas and pollution of the groundwater to the environment. The risk assessment are conducted on the open dumping area in order to evaluate the potential risk that occur at the open dumping area. The purpose of this paper is to evaluate the bearing capacity of the waste soil at the open dumping area. The risk assessment on the bearing capacity at the open dumping area are simulate using the Monte Carlo Simulations. The methodology starts from collecting the soil samples, conducting experiments such as sieve analysis test, specific gravity test and direct shear box test, and finally the analysis using Monte Carlo Simulation. Monte Carlo Simulation was used to decide or to make conclusion on the best probabilities for the bearing capacity at the open dumping area.

1. Introduction

Risk assessment is a systematic process of evaluating the potential risk that may be involved a projected activity or undertaking [1]. It covered hazard identification that is the risk factor that have potential to cause harm. In this research paper, the focus is to be evaluated the strength in shear of the soil in term of bearing capacity and total settlement for consolidation settlement and also elastic settlement in dumping area have done in past study. In this research is combination of both evaluation to be came with solution to determine the suitability for construction in dumping area at Sungai Ramal Dalam Kajang Selangor. In this term also, it is very important because for future development for instance like construction new building and infrastructure facilities, risk analysis also covered approximate solution to control risk when hazard cannot be eliminated. For example, in this geotechnical term it is very important to know the shear strength parameter and mineral content at open dumping area to ensure it does not gave the high risk for the future development. In another word, risk assessment is overall process of hazard identification and risk analysis and risk evaluation. (Canadian Standard association, CSA Z1002).

The risk analysis is very important because we need to identify the hazard of open dumping area to the environmental. This process requires some duration to complete, thus the Monte Carlo simulation method is used to save time and cost for the analysis of risk. The Monte Carlo simulation is very useful to support the reason why that particular place is not suitable for construction or in contrast maybe it also suitable for future development. Monte Carlo simulation is very useful to give the perspective in term of mathematically model to answers all the possibilities that can happened during development in that particular area. Bearing capacity at the dumping area was computed using Meyerhof model. For determination of bearing capacity of the soil it is important to know the soil profile and type of the soil in the sampling area. All civil engineering structures whether they are buildings, dams, bridges etc. are

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built on soils. A foundation is required to transmit the load of the structure on a large area of soil. The foundation of the structure should be so designed that the soil below does not fail in shear nor there is the excessive settlement of the structure. The conventional method of foundation design is based on the concept of bearing capacity. Soil when stressed due to loading, tend to deform. The resistance to deformation of the soil depends upon factors like water content, bulk density, angle of internal friction and the manner in which load is applied on the soil.

The bearing capacity is part of the risk parameter at the open dumping area. The risk assessment is calculated based on IRBA system which was developed by Kurian et al [2]. Risk assessment process is a set of logical, systematic and well defined activity that provide the decision maker with a sound of identification measurement and evaluation of the risk associated with natural phenomena or man-made action. In the risk assessment, all parameter need to be considered for example the distance of the dumping area to the nearest sources of water, the annual rainfall, the flood history at the dumping area, the settlement of waste, the distance from city and etc. The research is to estimate the risk assessment of the soil in terms of geotechnical part for future development, it also estimate the bearing capacity and total settlement. Monte Carlo Simulation was used to estimate the risk and the IRBA tools are used to calculate the score risk at the open dumping area

2. Risk Assessment at Open Dumping Area

2.1 *Risk assessment*

Risk assessment is a continually developing evaluation tool. This is not just in relation to landfills and other environmental issues but also in relation to other subjects and business fields including, the food industry, ecology, epidemiology, health physics, radiation, earthquakes, finance, construction management, building contract selection, insurance, economics, oil industry, business, regulatory systems, clinical governance and hospitals. However, literature on risk assessment that is related to environmental issues and specifically regarding landfills has been the main focus of the review in this paper. Regardless of the type of risk assessment and the environmental area of application, the basic theme or fundamentals are the same [3]. That is, there has to be a target/environmental receptor that may be affected by a hazard or unwanted event via a pathway. Similarly, there are three ways to control risks, which are: remove the hazards' source, remove the hazards' receptors, or manipulate the pathways between the source and receptors. For any of these ways, the information is to come from a risk analysis exercise. The hazard at the open dumping area that are the main focus in this paper is the bearing capacity of the soil at the dumping area.

2.2 *Bearing Capacity using Mayerhof Model*

For first determination is bearing capacity for shallow foundation. In this determination, we used the theoretical method. All the method got their limitation form example in Terzaghi bearing capacity theory got seven limitation there were, Depth of foundation is less than or equal to its width, Base of the footing is rough, Soil above bottom of foundation has no shear strength; it is only a surcharge load against the overturning load, surcharge up to the base of footing is considered, Load applied is vertical and non-eccentric, the soil is homogenous and isotropic. And L/B ratio is infinite. According to this limitation, the theory is not so accurate. In this research, the bearing capacity determination is using Meyerhof equation. This is because this theory is more accurate compare to the Terzaghi theory.

Meyerhof 1963 came out with the equation to consider all of the limitation in his equation. In Meyerhof analysis 1963, he made use of a failure mechanism. The expression for $N\gamma$ was obtained according to his previous theoretical analysis, combining with the experimental observation, Meyerhof work 1963 also included equations which account for the effects of footing shape and depth and the effect of load inclination. The shape factors obtained are partly theoretical and partly semi- empirical factors. He proposed expressions of depth factors which reflect approximate failure surface in many test results. The formula to compute the bearing capacity are as follows:-

$$Qu = c'N_c F_{cs} F_{cd} F_{ci} + qNqFqsFqdFqi + 0.5\gamma BN\gamma FysFydFyi \quad (1)$$

Where
Nc, Nq, Nγ = Bearing Capacity Factor,
C = cohesion,
Sq, Sc, Sy = Shape factor
Iq, Ic, Iy = Inclination factor
Dq, Dc, Dy = Depth Factor
γ = Unit weight of the soil below the foundation
D = depth of the foundation (depth of the sample)

2.3. *Monte Carlo Simulation Method*
Monte Carlo simulation is a computerized mathematical technique that allows people to account for risk in quantitative analysis and decision making. The technique is used by professionals in such widely disparate fields as finance, project management, energy, manufacturing, engineering, research and development, insurance, oil & gas, transportation, and the environment [4]. Monte Carlo simulation furnishes the decision-maker with a range of possible outcomes and the probabilities they will occur for any choice of action. It shows the extreme possibilities the outcomes of going for broke and for the most conservative decision along with all possible consequences for middle-of-the-road decisions.

The technique was first used by scientists working on the atom bomb; it was named for Monte Carlo, the Monaco resort town renowned for its casinos. Since its introduction in World War II, Monte Carlo simulation has been used to model a variety of physical and conceptual systems. Monte Carlo simulation performs risk analysis by building models of possible results by substituting a range of values a probability distribution for any factor that has inherent uncertainty. It then calculates results over and over, each time using a different set of random values from the probability functions. Depending upon the number of uncertainties and the ranges specified for them, a Monte Carlo simulation could involve thousands or tens of thousands of recalculations before it is complete. Monte Carlo simulation produces distributions of possible outcome values.

By using probability distributions, variables can have different probabilities of different outcomes occurring. Probability distributions are a much more realistic way of describing uncertainty in variables of a risk analysis. In this research the mean N value, Mean Confident, Mean 95%, Med, Min, Max Variance, Std. Dev, Confident SD 95%, and Std. Error was identified using Statistica software in order to summarize in risk assessment spread sheet.

3. Methodology
The methodology starts from the site selection for the study area. The site selection is based on the hazard found at the dumping area and the nearest location from UNITEN to collect the samples. The Sungai Ramal dumping area has been selected as the study area. The samples collected were then tested at the laboratory to obtain the shear strength parameters phi and cohesion for bearing capacity calculations. The soil parameters from laboratory testing is used for the analysis in the Monte Carlo Simulations.

3.1. Site Selection
Since more than a year ago, the air release at the Taman Suria in Sungai Ramal Dalam mixed with foul smoke suffocating. Smoke was coming from open burning in an open area where the trash disposal by irresponsible person, and no party have taken any action to stop it. Review Utusan Malaysia at that location recently found all kinds of garbage burned in situ and the region as a volcanic crater that will explode due to the smoke coming out of the ground. In fact, since the illegal activity began over a year ago, many flies were found on the food when preparing meals at home. The dumping area at Sungai Ramal Dalam has the thickness of the waste about 5 meter height and the soil there have the combinations of concrete debris, concrete waste, some twigs, paper and aluminium can. This dumping area has been abandoned for quite some time.

3.2. Direct Shear Box Test

Samples collected at the dumping area are also tested with direct shear box test to determine its cohesion and friction angles. The test is carried out on either undisturbed samples or remolded samples. To facilitate the remolding purpose, a soil sample may be compacted at optimum moisture content in a compaction mold. Then specimen for the direct shear test could be obtained using the correct cutter provided. Alternatively, sand sample can be placed in a dry state at a required density, in the assembled shear box.

A normal load is applied to the specimen and the specimen is sheared across the pre-determined horizontal plane between the two halves of the shear box. Measurements of shear load, shear displacement and normal displacement are recorded. The test is repeated foe two or more identical specimens under different normal loads. From the results, the shear strength parameters can be determined.

3.3. Monte Carlo Simulations

Monte Carlo simulation performs risk analysis by building models of possible results by substituting a range of values a probability distribution for any factor that has inherent uncertainty. It then calculates results over and over, each time using a different set of random values from the probability functions. Depending upon the number of uncertainties and the ranges specified for them, a Monte Carlo simulation could involve thousands or tens of thousands of recalculations before it is complete. Monte Carlo simulation produces distributions of possible outcome values.

By using probability distributions, variables can have different probabilities of different outcomes occurring. Probability distributions are a much more realistic way of describing uncertainty in variables of a risk analysis.

In this research the mean N value, Mean Confident, Mean 95%, Med, Min, Max Variance, Std. Dev, Confident SD 95%, and Std. Error was identified using Statistica software in order to summarize in risk assessment spread sheet.

4. Results and Discussions

4.1 Direct Shear Box Test results

In this research the shear stress and shear displacement were plotted against in each other and the normal loading for the shear testing are 2kg, 4kg and 6kg. The graph for the plot are shown in Fig. 1, Fig. 2 and Fig. 3. The graph shows that the shear stress increases with shear displacement.

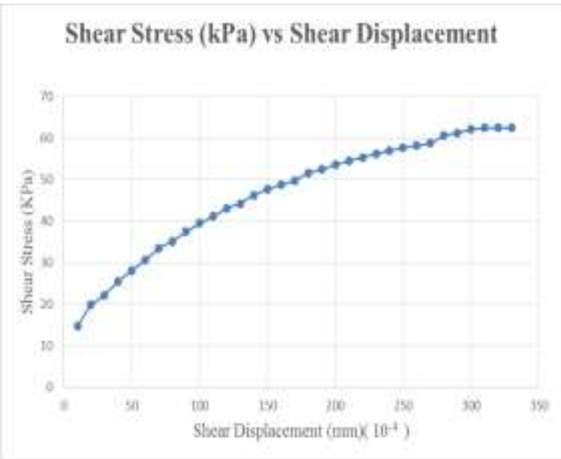

Figure 1. Shear Stress versus Shear Displacement for 2 kg normal load.

Figure 2. Shear Stress versus Shear Displacement for 4 kg normal load.

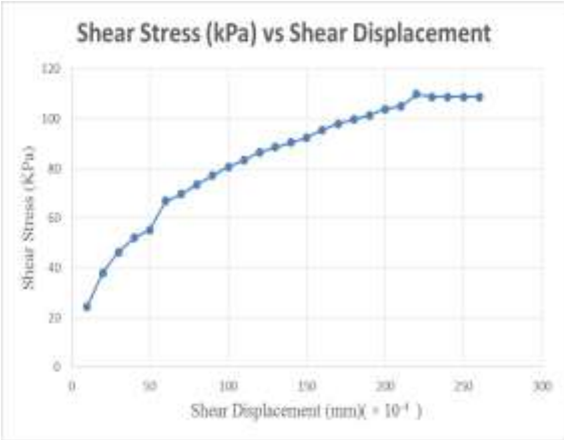

Figure 3. Shear Stress versus Shear Displacement for 6 kg normal load.

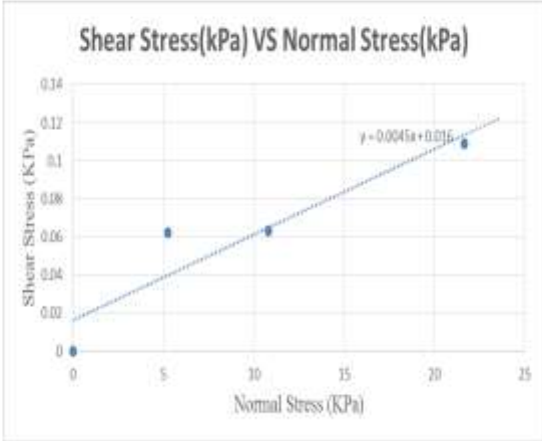

Figure 4. Shear Stress versus Normal Stress for 2 kg, 4 kg and 6 kg.

Table 1. The friction angles and cohesion of the samples at dumping area.

Sample No.	Shear Strength Parameters	
	Friction Angle (^{0})	Cohesion (kPa)
1	0.18	0.0175
2	0.05	0.0511
3	0.2	0.0160

The friction angle and cohesion has the average values of 0.14^0 and 0.0282 kPa. The samples have low friction angles and low cohesion values.

4.2 Monte Carlo Simulation results
Based on the experimental results, the Monte Carlo simulations are used to simulate the experimental data with N = 10 number of iterations for Case1, Case 2 and Case 3. Case 1 is where the average value for bearing capacity is 23.58 kPa. As for Case 2 and Case 3, the average bearing capacity is 25.46 kPa and 24.64 kPa respectively. The analysis using Monte Carlo simulation is shown in Fig. 5, Fig. 6 and Fig. 7.

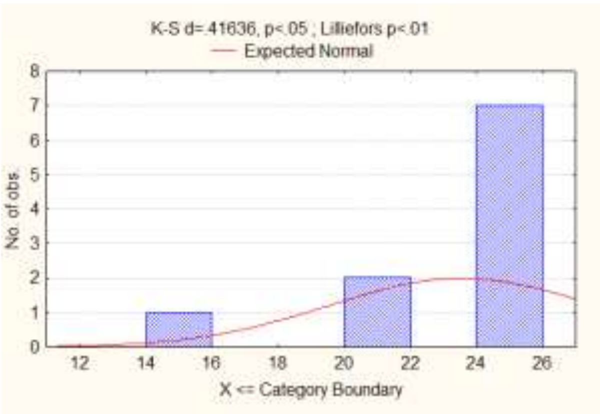

Figure 5. The number of Frequency against bearing capacity for Case 1 with N = 10 number of iterations.

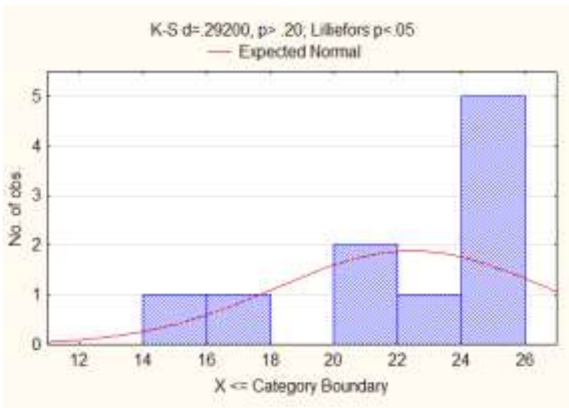

Figure 6. The number of frequency against bearing capacity for Case 2 with N=10.

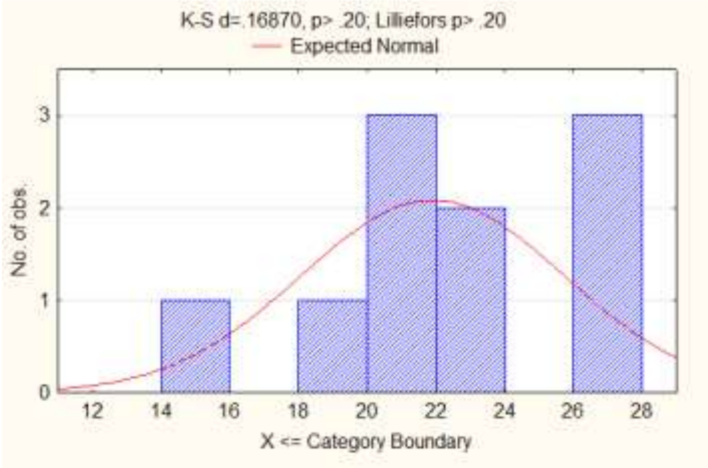

Figure 7. The number of Frequency against bearing capacity for Case 3 with N = 10 number of iterations.

Based on the Monte Carlo Simulation results, the mean value for bearing capacity is 26.44 kPa for Case 1, 25.47 kPa for Case 2 and 24.64 kPa for Case 3. The histogram shape show the normal distribution curve although the number of iterations are only limited with N=10. Further analysis with N= 20, 50 and N =100 could have given a full bell shaped curved. Table 2 summarize the statistical parameters for the bearing capacity data at the dumping area.

Table 2: Statistical parameters for Case 1, Case 2 and Case 3.

Sample No.	Statistical Parameters			
	Confident Mean 95%	Standard Deviation	Variance	Mean
Case 1	26.44	4.003	16.03	23.58
Case 2	25.47	4.233	17.92	22.42
Case 3	24.64	3.831	14.68	21.90

4.3 Discussion

The dumping area at Sungai Ramal Dalam has been identified as stable based on the experimental data direct shear test and the Monte Carlo simulation. The experimental data with limited samples give low friction and cohesion value which is 0.14^0 and 0.0282 kPa. Further analysis using Monte Carlo simulations with N =10 number of iterations, the cohesion and friction angle gives the bearing capacity of 26.44 kPa for Case 1, 25.47 kPa for Case 2 and 24.64 kPa for Case 3. When compared the data with other researcher [1], the bearing capacity computed is 3307.63 kN/m^2 with the average friction angle 32^0 and cohesion 33.8 kPa assuming the width of shallow foundation is 1 meter. The average friction angle and cohesion based on the published data [5]. The depth of groundwater level are between 0.5 meter and 5 meters.

5. Conclusion

In conclusion, the Sungai Ramal Dalam dumping area are stable and suitable for post development. The hazard at the area has been identified which are the bearing capacity and the stability of the slopes at the dumping area. The friction angle and cohesion have been determined from the experimental data. The experimental data has been simulated using Monte Carlo simulations and gave a stable value of bearing capacity which are 26.44 kPa. Both Monte Carlo simulations and the experimental data agrees that the open dumping area at Sungai Ramal Dalam are possible to be developed for future constructions.

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