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Investigation of Settlement of Contaminated Waste Soil at an Open Dumping Area

Eva Lailatun Nisa Fatdillah and **Nur Irfah Mohd Pauzi**

Civil Engineering Department, College of Engineering, Universiti Tenaga Nasional, Putrajaya Campus, KM7, Jalan IKRAM-UNITEN, 43009 Kajang, Selangor
e-mail: irfah@uniten.edu.my

ABSTRACT

Uncontrolled MSW disposal usually dumped at the improper dumping area and eventually will contaminate the soil then creating unhealthy environment to society and unsafe condition for future land-use planning. This paper aims to investigate the contaminated soil geotechnical properties and the settlement occurs at open dumpsite in Jalan Akob, Kapar, Klang. Three experimental lab namely SEM EDX Test, Sieve Analysis Test and Direct Shear Test are carried out for both samples to obtain soil parameters before analyzing it. Based on the geotechnical properties obtained, settlement is analyzed and estimated using Schmertmann Strain Factor Method. The results shows that the settlement occurs is 3.338 x 10-3 mm and it is within the allowable limit which is less than 25 mm according to Malaysia’s standard guideline. Previous study shows that many methods discovered to improve the load bearing capacity of the soil to help reducing the settlement such as applying bamboo and geogrid reinforcement.

KEYWORDS: Settlement Model; Contaminated Waste Soil; Open Dumping AreaSEM EDX Test; Remediation

INTRODUCTION

Increasing the number of population effecting the amount of Municipal Solid Waste (MSW) produced and the properly management of MSW has becomes a concern to the most countries. Ineffective management of MSW will lead to new problems to the environment and to the society. Uncontrolled MSW disposal usually dumped at the improper dumping area and eventually will contaminating and deteriorating the quality of the soil. Highly contaminated soil will introduce unhealthy environment to society and unsafe condition for future land-use planning. Non-availability and low cost for waste disposal cause the open dumping becomes the common option in developing countries (Ali & Yasmin, 2014). Open dumping are usually unsightly view and generally smelly that possible to attract scavenging animals like rats, cockroach and other pests.

Contaminated soil is quite different with normal soils due to the composition of it that not only consist of sand, clay and silt but also others materials from domestic or industrial wastes such as debris, food, decayed wood and etc. The waste soil which has undergone the weathering process, percolation and infiltration of water has changed its characteristics as compared to normal soil (Pauzi et al., 2014). We are currently far from fully understanding the waste soil due to the heterogeneous contain in waste soil so the researchers rely on the behavior of soil. Unit weight and shear strength parameters are two crucial properties in evaluating the stability of waste soil.

For waste contaminated soil, it is possible for secondary settlements occurs due to the creep of waste skeleton and biological decay (Nawagamuwa & Muhilan, 2015). In this cases, secondary compression accounts a significant part of total settlements and it may happened for many years. There are four types of settlement model that helps to stimulate the mechanical behavior of contaminated soil; soil mechanics based model, empirical model, rheological model and incorporate biodegradable model (Hosni.et al., 2015).

Soil settlement estimation methods is depending the type of soil and its particle gradation. Soil can be classified into two based on the particle size; granular soil and cohesive soil. Granular soil includes sand and gravel while cohesive soil includes silt and clay. Table 1 show the summarization of settlement estimation method based many researchers.

Table 1: Summary of Settlement Estimation Methods

Methods	**Equation**
Terzaghi/Skempton (1943)	$\mathrm{S_i} = \frac{\mathrm{qB}}{\mathrm{E}} (1 - \mathbf{v^2})\, \mathrm{I_p}$
Steinbenner (1934)	$\mathrm{S_i} = \frac{\mathrm{qB}}{\mathrm{E}} (1 - \mathrm{v}^2)\, \mathrm{I_s}$
Janbu et. al (1956)	$S_i = \frac{qB}{E} v_0 v_1 (1 - v^2)$
Schmertmann (1970)	$S_i = \frac{qB}{E} v_0 v_1 (1 - v^2)$
Young's Modulus Elasticity Method (1997)	$\Delta \mathrm{S} = \frac{\mathrm{PH}}{\mathrm{A}E_S}$
Hossain and Gabra (2005)	$\frac{S_i}{H} = X_{\alpha 1} \lambda O \gamma (\frac{t_2}{t_1}) + X_{\beta} \lambda O \gamma (\frac{t_3}{t_4}) + X_{\alpha \phi} \lambda O \gamma (\frac{t_4}{t_3})$
Edil et. al (1990)	$S_i = H_0 \Delta\sigma M' (\frac{t}{t_r})^{N'}$
Gibson and Lo (1961)	$\frac{S_i}{H_0} = \Delta\sigma\alpha + \Delta\alpha\beta(1 - \varepsilon^{-(\frac{\lambda}{\beta})\tau})$
Park and Lee (2007)	$\varepsilon(\tau)_{\delta\varepsilon\chi} = X_\alpha \lambda 0 \gamma (\frac{t_2}{t_1})$

	$\varepsilon(\tau)_{\delta\varepsilon\chi} = \varepsilon_{\tau o \tau_{\delta\varepsilon\chi}}(1 - e^{-k_1})$

The objective of this study is to investigate the geotechnical properties of the contaminated waste soil in study area. This geotechnical properties is essential in determine the settlement occurs. Proper measurement can be taken to reduce the possibility of failure after obtaining the geotechnical properties and the settlement and act of remediation to treat contaminated land for future land-use planning.

The author combines the application of SEM EDX Test which usually used in bio-science field in the geotechnical field. This knowledge could be enhanced to examine the mineral compositions of samples and the connection with the geotechnical properties of soil. It helps to establish the possible presence of inert material that will harm the soil quality and lead to worse effect to society and environment. In this paper, the soil only undergo a process to determine the mineral compositions as to know the hazardous content of the soil.

METHODOLOGY

Figure 1 shows the flowchart of the summarization on how the research study is carried out to obtain the results and achieving the objectives. The study started with the selection of study area to get the soil sample. Next, literature review is to review the previous work that has been done on the research area and enhance the new knowledge for current development in the field of study. This will help to visualize the possible outcomes and to plan how the research study will be carried out. After the confirming the study area and done with desk study, soil is sampled and taken to the lab for testing. For this study, there are four experimental lab are done; SEM EDX Test, Sieve Analysis Test and Direct Shear Test. The lab results are obtained and analyzed.

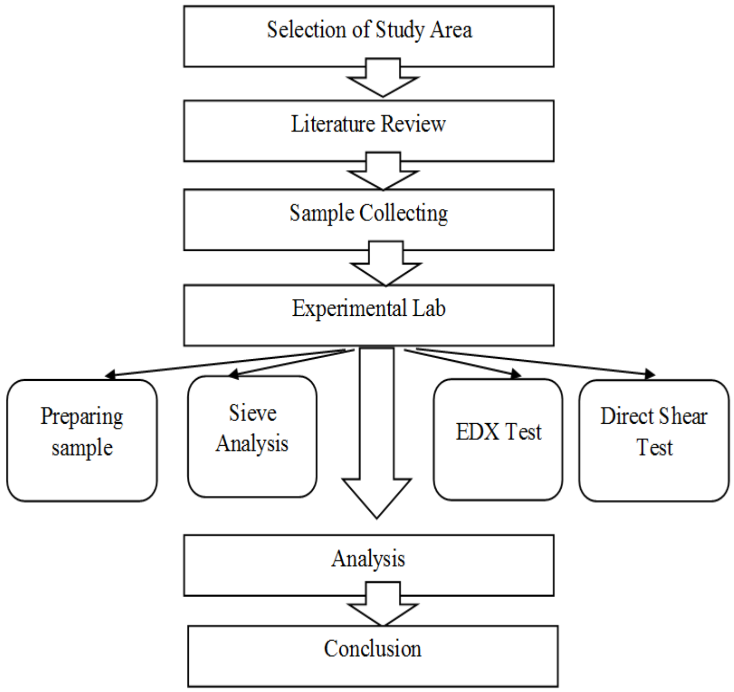

Figure 1: Summarization of the methodology

RESULTS AND DISCUSSIONS

All the data obtained from the experimental lab is analyzed to study the properties of the soil and deciding the best method to estimate settlement. Figure 2 shows the gradation curve of two samples. Both samples are classified as poorly-graded sand soil with coefficient of curvature, C_c ranges are more than 3 and coefficient of uniformity, C_u is more than 2. For sample 1, the C_c is 2.165 and C_u of 7.67. It consists of 72.6% of course sand, 12.25% of medium sand and 10.125% of fine sand and approximately 5% of silt. For sample 2, the C_c is 1.24 and C_u of 6.375. It consists of 61.55% of course sand, 14.15% of medium sand, 19.295% of fine sand and approximately 5% of silt. The samples taken are mostly course particles, probably due to it is obtained at the approximately 0.5m depth from the surface. The gradation of soil is the main influence of compaction. Poor graded soil will introduce the air void between the particles and enhance settlement of soil when load is applied on it.

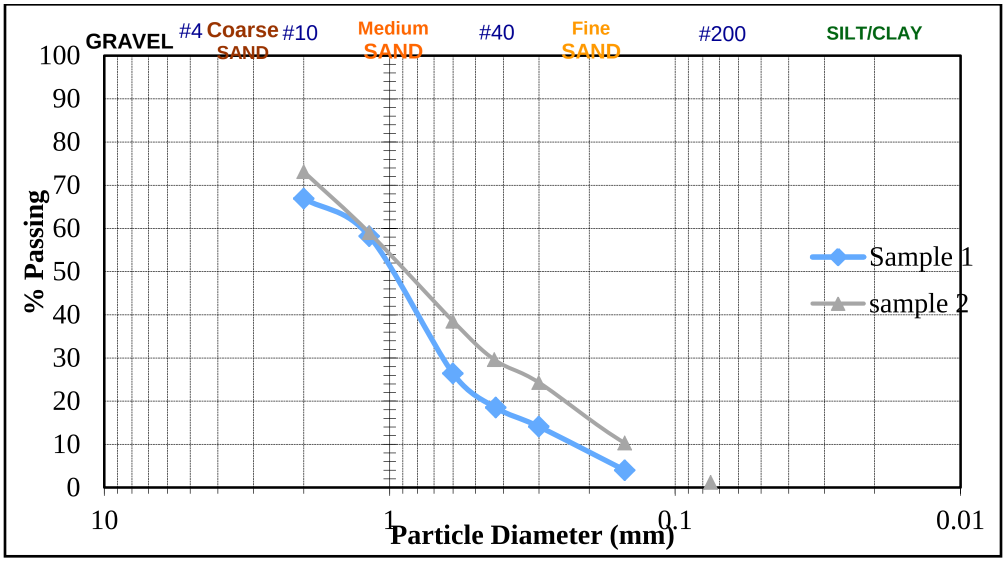

Figure 1: Grain Size Distribution Curve of Sample 1 and Sample 2

SEM EDX Test results shows the mineral composition of the soil to help in having better understanding the soil and to investigate the presence of inert material in the soil briefly. Table 2 and 3 shows the percentage of mineral composition in the soil and shows absence of inert materials. It shows that the soil composed mostly by carbon, oxygen, silica and iron. In this sample, there are some aluminium and potassium that are the waste materials.

Table 2: Percentage of mineral composition in sample 1

Spectrum	In stats.	C (%)	O (%)	Al (%)	Si (%)	K (%)	Ca (%)	Fe (%)	Total (%)
Spectrum 1	Yes	12.97	48.80	8.76	12.49	1.71	0.34	14.92	100.00
Spectrum 2	Yes	0.00	49.41	11.21	16.48	3.73		19.16	100.00
Spectrum 3	Yes	26.76	48.67	6.95	11.61	1.14		4.87	100.00
Max.		26.76	49.41	11.21	16.48	3.73	0.34	19.16	
Min.		0.00	48.67	6.95	11.61	1.14	0.34	4.87	

Table 3: Percentage of mineral composition in sample 2

Spectrum	In stats.	C (%)	O (%)	Al (%)	Si (%)	K (%)	Ca (%)	Fe (%)	Total
Spectrum 1	Yes	12.97	48.80	8.76	12.49	1.71	0.34	14.92	100.00
Spectrum 2	Yes	0.00	49.41	11.21	16.48	3.73		19.16	100.00
Spectrum 3	Yes	26.76	48.67	6.95	11.61	1.14		4.87	100.00
Max.		26.76	49.41	11.21	16.48	3.73	0.34	19.16	
Min.		0.00	48.67	6.95	11.61	1.14	0.34	4.87	

Failure plot is created according to maximum shear of the sample and normal stress applied to the sample. Based on failure plot linear line, the slope is the angle of internal friction, ϕ of the sample and the y-intercept is the cohesion. For sample 1, the ϕ is 15.658° and c is 2.315kPa. Angle of internal friction depends on void ratio and shape of particles, decay of organic matters and other pollutants to make the soil particles more granular. It reduces the angle of internal friction but increases the cohesion of the soil (Borude & Patil, 2016).In failure plot graph, the shear stress is directionally proportional to normal stress. For sample 2, the ϕ is 5.603° and c is 4.4815kPa.

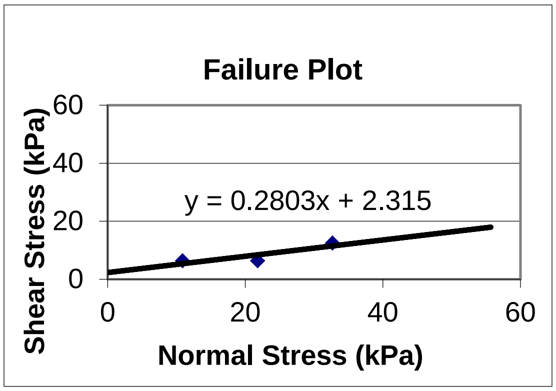

Figure 3 (a): Sample 1

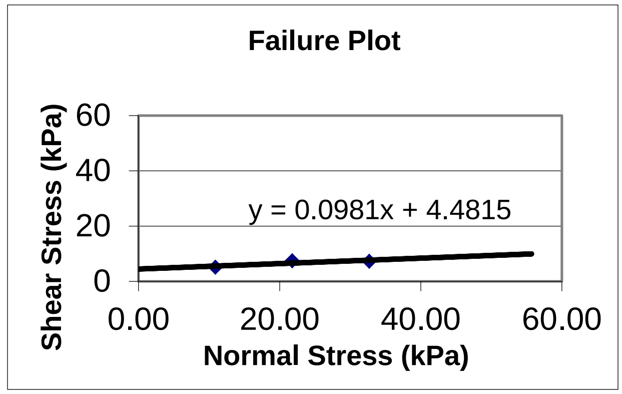

Figure 3 (b): Sample 2

Figure 2: Failure plot for both samples

Shear failure occurs when the stresses between the particles are such that they slide or roll past each other. As discussed, data shows that the samples are poorly graded and it increase the number of possibility of the particles to slide and roll past to each other. The shear strength for sample 1 is 18.169kPa and 7.264kPa for sample 2. , the shear strength of Sample 1 is slightly higher than Sample 2 but the strength is significantly lower than normal soil. It is due to the degradation of MSW that influence the gradation of the soil. Poor graded soil enhance the percentage of the soil particles to slide each other and increase the stress failure.

The soil is classified as granular soil as it consists of 95% of sands. For granular soil, the settlement occur very quickly after the placement of foundation or infrastructures and it is typically very small. If the in-situ granular soils is very loose, it will lead to large elastic settlement. To estimate the settlement in this study, the Schmertmann Strain Factor Method is applied as shown in Figure 4.11. This method is widely used practice today to estimate settlement under center of footing.

$$S_i = C_1 C_2 q_{net} \Sigma \frac{I_z \Delta z}{E_s} \tag{1}$$

In this calculation, the author assume the traffic load is 10kPa and the depth is 0.15m for top soil and estimating for 1 year after a placement with the value of CPT is 1000MPa. The calculation results that both samples indicate same amount of settlement which is 3.338 x 10^{-3} mm and it is within the allowable limit according to Malaysia's guideline which is 25mm. Wetting-induced change in the state of soil's structure under self-weight can introduce the settlement in sandy soils (Lommler, 2012). This is called as soil collapses. In other word, the soil is able to collapse due to its own weight.

In the same study, Lommler (2012) stated that loading of granular soil can cause settlement due to the increasing normal and shearing stress in the soil mass.

Granular soils can be improved its strength by applying few different methods such as vibro-flotation, compaction piles, compaction with explosives, excavation and replacement, well point system, reinforced earth, grouting, etc., (Santhosh Kumar, T. G., Abraham & Sridharan, 2015). Islam et al., (2014) presents the results of soil improvement using bamboo reinforcement to reduce the settlement of soil. It shows that the load bearing capacity of the soil is increased by placing the bamboo reinforcement within the depth of envelope failure. Yaseen et al., (2009) analyzed that by making square trench under the footing with the same dimensions of it for different depth helps in improving the bearing capacity of soft soils. Jawad et al., (2010) studied the behavior of geo-grid reinforcement in the loose sandy soil that subjected to eccentric load. The study results the improvement of bearing capacity by 20% for single reinforcement sand layer and up to 47.5% for two layers for different eccentricity values.

Several remediation measures can be done in contaminated soils for land use planning and development depending on the site-specification situation. The utility of any one soil remediation technique invariably depends on the nature of contamination and the level of risks posed by the contaminants (D. Kofi, 1996). The needs of various stakeholders should be taken into account and analyzed quantitatively, including the needs of the local governments responsible for remedial activities, cities (or towns or villages) with illegal dumping sites, the property owners and neighboring residents, and the taxpayers who indirectly pay for remediation (Ishii et al., 2013).

According to (Wood, 1997), there are three abroad methods of remediation.

1. Engineering approaches - Landfills
2. Technical approaches – Physical, biological, chemical, thermal and stabilization process
3. Hydraulic measures and natural attenuation.

CONCLUSIONS

In this paper, the author is investigating the settlement of the contaminated soil in the dumping area. The objectives of this research study is to investigate the geotechnical properties of the soil sample and to estimate the settlement of the soil in the study area then proposing proper measurements due to settlement and contamination in the soil.

Based on the direct shear test, the internal angle of friction and cohesion of the soil are obtained. For sample 1, the ϕ is 15.658˚ and c is 2.315 kPa and the ϕ is 5.603˚ and c is 4.4815 kPa for sample 2. This data is used to determine the shear strength before estimating the settlement of the soil. The shear strength for sample 1 is 18.169 kPa and 7.264 kPa for sample 2.

Based on the geotechnical properties obtained, settlement is analyzed and estimated using Schmertmann Strain Factor Method where the author is assuming the traffic load is 10 kPa and the depth is 0.15 m for top soil and estimating for 1 year after a placement with the value of CPT is 1000 MPa. The results show that the settlement occurs is 3.338 x 10-3 mm and it is within the allowable limit according to Malaysia’s guideline which is 25 mm.

Previous study shows that many methods discovered to improve the load bearing capacity of the soil to help reducing the settlement such as applying bamboo and geogrid reinforcement. Remediation of soil can be categorized into three wide class which is engineering approaches, technical approaches and hydraulic approaches. Engineering approaches includes include landfill where it is an engineered design to isolate the contaminants from harming the environment. Technical approaches involves physical techniques, biological techniques, and stabilization of the soils. Hydraulic approaches consist methods in controlling groundwater flow to control the contaminants discharge. For Kapar study area, it was proposed to excavate the soil that was soft and replace with the new soils so that there will be no settlement at the dumping area

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