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Effect of Lead on Strength Behaviour for Spiked Contaminated Soil

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ABSTRACT

Deterioration of geo-environmental quality caused by the heavy metal in contaminated soil leads to changes in physical, mechanical, and chemical properties of soil. It is important to study the effect of contamination of the geotechnical properties of soil. The main aim of this research is to study the impact of lead and incubation time on polluted soil compressibility. The soil samples were got from Kaolin Malaysia Sdn Bhd in Tapah Perak. The soil samples were spiked with two concentrations of lead nitrate (1000 mg/kg and 2000 mg/kg), and were incubated for 7, 14, 21, and 28 days. The contaminated samples were created using a mixture of distilled water and lead nitrate. The physical, mechanical, and chemical properties of control and contaminated samples were assessed to analyse the effect of lead nitrate on these properties. Lead nitrate causes the increasing of plastic limit and liquid limit, reduction of maximum dry density and optimum moisture content. In addition, the unconfined compressive strength was decreased by 4.2% for 1000mg/kg while 24.3% with 200 mg/kg. This is with increasing concentration of lead nitrate as well as incubation period. Collapsibility increases with increased concentration of lead nitrate and time of incubation due to increased compressibility capacity. The important thing about this study is to provide a database for the future development of the site area contaminated with heavy metals such as landfill, landfill, agriculture and industry.

Keywords: Lead; heavy metal; contaminated soil; spiked soil; strength

INTRODUCTION

Contaminated soil is one of the serious issues should be focus all on the world. The contamination in soil may affect the properties of the original soil (virgin soil) itself either in physical, chemical, and geological of the soil. Besides, this issue is getting worse when the sources of the pollution increasing year by year. The cause of the pollution and increasing of the heavy metal in soil comes from improper disposal practices, industrial activity, mining activity, agriculture activity, wastewater discharge (Ahmad et al. 2021). Wastes generated by developed and developing countries alike are increasing because of a rise in affluence and improved living stan- dard. The increase in the amount of waste generated in the cities has emerged as a major concern over the past years. The total amount of waste generated annually worldwide is more than 4 billion tons and is increasing significantly. Global urban municipal solid waste (MSW) production has been projected to increase from 1.3 billion tons in 2010 to 2.2 billion tons in 2025 (Dutta & Mishra, 2017). The most common heavy metal involved are Pb, Cd, Hg, Cu, Fe, Mn and As. Some of the heavy metal required in minute quantities by organisms but some of the heavy metal can be threat and harmful to the environment (Zhai et al. 2018) (Pineda, 2021). Although the heavy metals are naturally present in soil, the activities mentioned above are the booster of the increasing of the heavy metal in soil. The long-term exposure and accumulation of these nanoparticles in the soil may affect soil nutrient and organic matter contents (Ren et al. 2022). In addition, the present of heavy metal in soil may affect the physical properties, mechanical properties, and chemical properties of soil itself. The strength of the soil can also be increased or decreased depending on the types of heavy metals and soil properties.

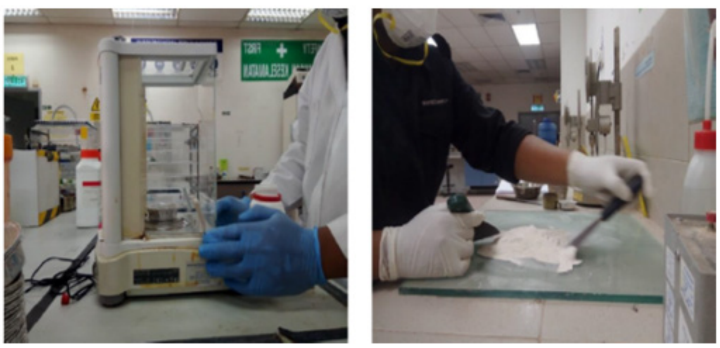
The remediation of contaminated soil through heavy metal removal has been a topic of interest in soil stabilization research. Different approaches have been explored, including the use of adsorption, absorption, and sorption materials such as fly ash, cement, and lime, among others. Based on research carried out by other researchers, the present heavy metals in the soil can alter the physical, mechanical and chemical properties of the soil (Li et al. 2019). Physical properties such as Atterberg limit, optimum moisture content and maximum dry density change due to different concentration of the Lead nitrate ($Pb(NO_3)_2$, for mechanical properties represent the reduction of strength due to increasing of concentration and incubation of Lead nitrate and reduction of pH can be seen for chemical properties of the soil after present of lead nitrate (Negahdar & Nikghalbpour 2020). The main objective of this paper is to examine how the presence of lead affects the compressibility of contaminated soil spiked with the heavy metal.

METHODOLOGY

PREPARATION OF SPIKED CONTAMINATED SOIL

The sample used was White Kaolin Clay. The sample collected from Kaolin Malaysia Sdn Bhd. The site is located at Batu 38 ¾, Jalan Tapah – Bidor, 35000 Tapah, Perak Malaysia. Figure 1 illustrates that the sample has a white color and fine particle texture. The physical properties of the kaolin are as follow, moisture content below 1.0 %, pH (30% solid) in between 4.0 to 5.5, whiteness 89.0 – 91.0%, 325 mesh residue below 0.01%. and average particle size is in between 1.0 – 1.5 µ. For spiked sample, the heavy metal used are lead nitrate with concentration 1000 mg/kg and 2000 mg/kg. The optimum water content and maximum dry density for each sample were determined by using the standard proctor compaction test. The dry soil then mixed with the heavy metal with stated concentration. In Figure 2(a), lead nitrate is being weighed, and in Figure 2(b), it is mixed with kaolin using a spatula. The mixture was left for 30 minutes before the optimal water content was added.

FIGURE 1.Kaolin sample



(a) (b)

FIGURE 2. (a) Weight the Lead nitrate by using weight balance. (b) Process of mixing kaolin with Lead nitrate

ATTERBERG LIMIT

The objective of Atterberg limit test is to determine the liquid limit and plastic limit of soil samples for identification of dried soil. The overall procedure of Atterberg limit test is based on British Standard (BS1377: Part 2: 1990)

STANDARD PROCTOR COMPACTION TEST

The main objective of conducting the Standard Proctor Compaction test is to analyse the compaction characteristics of the soil. While water acts as a lubricant between the soil particles, an increase in its content may lead to the occupation of all the pores. This can restrict compaction since water is relatively incompressible compared to air. The standard Proctor Compaction Test is used to determine the maximum dry density and optimum water content of the soil sample. The overall procedure for the Standard Proctor Compaction test is according to British Standard (BS1377: Part 2: 1990).

UNIAXIAL COMPRESSION TEST

The purpose of Uniaxial Compression test is to determine the unconfined compressive strength of a cohesive soil. The Unconfined compressive Testing oil sample mould is 38 mm diameter and 75 mm height. The cylindrical sample was compacted in the mould using five layers, with each layer receiving 50 blows, as shown in Figure 3(a) and 3(b). Following this, the sample was incubated in the incubator for 7, 14, 21, and 28 days before being processed, as illustrated in Figure 3(c). The overall procedure for the unconfined compressive test for the sample is according to British Standard (BS 1377: Part 7: 1990).

(a) (b) (c)

FIGURE 3.(a) sample is wrapped with plastic wrap as first layer (b) sample is wrapped with aluminum foil as second layer (c) sample placed in incubator for incubation process.

pH TEST

The pH test was performed to determine the soil sample pH value. pH of each sample was tested every 7, 14, 21 and 28 days for every concentration. 30 gram of soil sample mixed with 75 ml of distilled water and the reading taken after 8 hours. The standard procedure for pH test is according to British Standard (BS 1377: Part 3: 1990).

RESULTS AND DISCUSSION

ATTERBERG LIMIT

Liquid Limit (LL) and Plastic Limit (PL) shows the increasing trend shown in Table 1 and presented also in Figure 4, where the lowest percentage is at control sample with 31.40% and the highest is 34.23% for the 2000 mg/kg for the LL. The soil sample plastic limit shows the increased percentage for uncontaminated and contaminated soil with Lead nitrate. 28.34% for uncontaminated sample and increased to 30.34% and 31.985% for 1000mg/kg and 2000mg/kg respectively. In line with the research conducted by Abidoye et al. (2018), the results of this study demonstrate a similar trend. The contaminated samples exhibited a notable decrease in Plasticity Index, with the lowest concentration of 1000 mg/kg displaying a value of 1.73%, in comparison to the non-contaminated samples at 2.25% and the uncontaminated samples at 3.05%.

The presence of Lead nitrate causes the increasing of Liquid limit and plastic limit of the contaminated soil, the result indicates that the soil samples having the exchange discharge of hydroxide ion cation. The imbalance negative ions have balancing by the hydroxide ion that absorb more water in the kaolin clay particles. This is important to highlight that the ion Pb2+ play an important role to the increasing the plastic limit and liquid limit (Taheri et al. 2018). The increase in plasticity in the contaminated soil causes the problem related to deteriorate the quality of soil in the engineering material.

TABLE 1. Liquid limit, plastic limit and plasticity index

Sample	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
Control	31.40	28.34	3.05
1000 mg/kg	32.07	30.34	1.73
2000 mg/kg	34.23	31.98	2.25

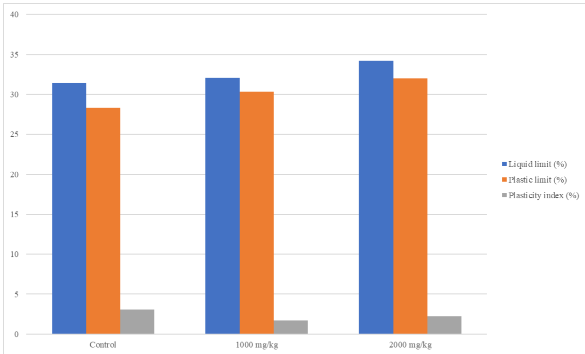


FIGURE 4. Liquid limit, plastic limit and plasticity index

MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE CONTENT

Figure 5 shows that there are slightly different between uncontaminated sample and 1000 mg/kg of lead nitrate contaminated soil with 1.7 mg/kg and 1.96 mg/kg respectively of maximum dry density. The graph also shows the sample with 2000mg/kg of lead nitrate have least value of maximum dry density with 1.67 mg/kg. In addition, it is also affected by the moisture content of the soil samples. Graphs show the value of Optimum Moisture Content is 18.3%, 16.0% and 16.7% for uncontaminated sample, 1000 mg/kg and 2000 mg/kg of lead nitrate, respectively. The study shows that the Optimum Dry Density (MDD) and Optimum Moisture Content (OMC) are changes with different concentration of Lead nitrate contamination. Its shows that the Maximum Dry Density decrease with increasing the concentration of lead nitrate. This result has the same output as the research with the other researchers (Abidoye et al. 2018) where it indicates the MDD decreased with the increasing of concentration of Lead nitrate in the contaminated soil and the OMC reduced with increasing of concentration of lead nitrate. The other study by (Zheng et al. 2019) in his research show the same result for optimum moisture content which the increasing of concentration lead contamination affect the decreasing of optimum moisture content. This study shows the increasing concentration of lead contaminant reduces the maximum dry density and optimum moisture content.

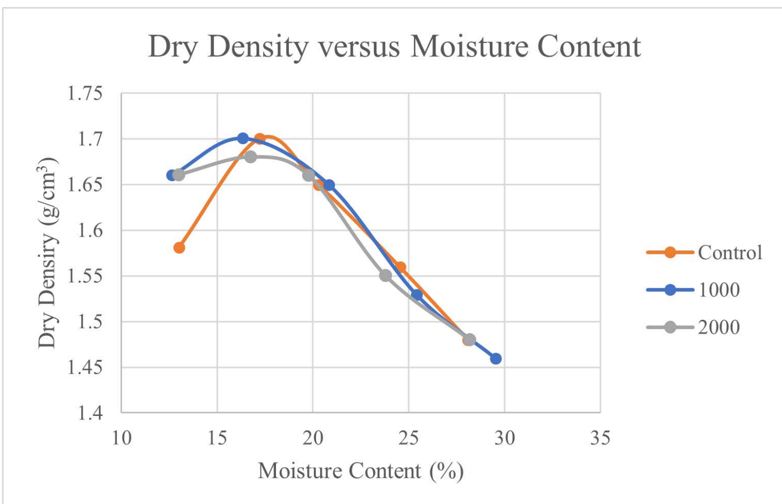


FIGURE 5. Graph Dry Density Versus Moisture Content

The evident that the presence of lead cause the reduction of maximum dry density and optimum moisture content is shows by the compaction properties. The reduction maximum dry density and optimum moisture content reflect the interaction between lead and clay parts. Lead contamination in soil prevent the interaction between the water and the clay particles. As the result, the increasing of concentration of lead reduces the amount of water for the kaolin clay reach the maximum dry density. Lead contaminations cause the effect of the maximum dry density and optimum moisture content because its breakdown the bonding particles in the soil structure that cause the easily breaks due to hammering process (Islam et al. 2019)

UNCONFINED COMPRESSION TEST

Figure 6 depicted the development profile of UCS in the different concentration of Lead nitrate at 7, 14 and 21 days. UCS of the lead contaminated decrease with the increase in incubation period. The least strength of the reduce from 128.558 kPa to 114.7 kPa at 7 days for 2000 mg/kg concentration and increase to 133.325 kPa for 1000 mg/kg concentrations respectively. The strength is increase because is due to loss of moisture that makes the soil harden over times. The strength of the contaminated soil shows the decreasing trend when the increasing of incubation period. However, the result of 1000 mg/kg of lead contaminated shows the strength of the soil samples is higher than the uncontaminated sample. The strength of the sample at 28 days are 123.095 kPa and 97.325 kPa for 1000mg/kg and 2000 mg/g of Lead nitrate respectively. It is important to note that the UCS decrease for further increase of the concentration of Lead nitrate and incubation period. (Muththalib & Baudet, 2019) and (Karkush & Ali, 2020). In their findings it was agreed that the unconfined compressive strength decreasing due to presence of heavy metal. The result obtained by the previous researcher. Figure 7 shows there are slightly different of the UCS value for the sample at 14 days and 21 days of incubation period for both concentrations.

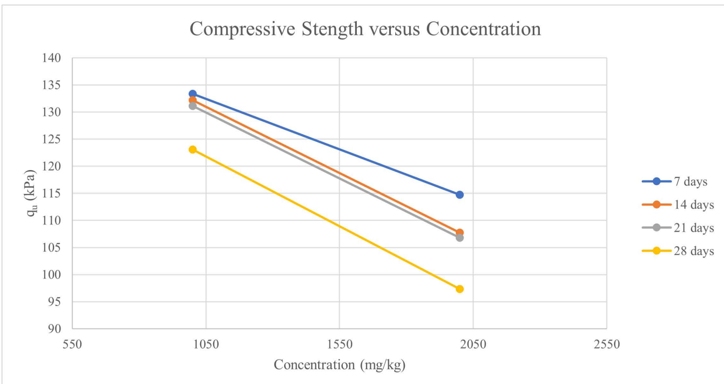


FIGURE 6. Strength Versus Concentration

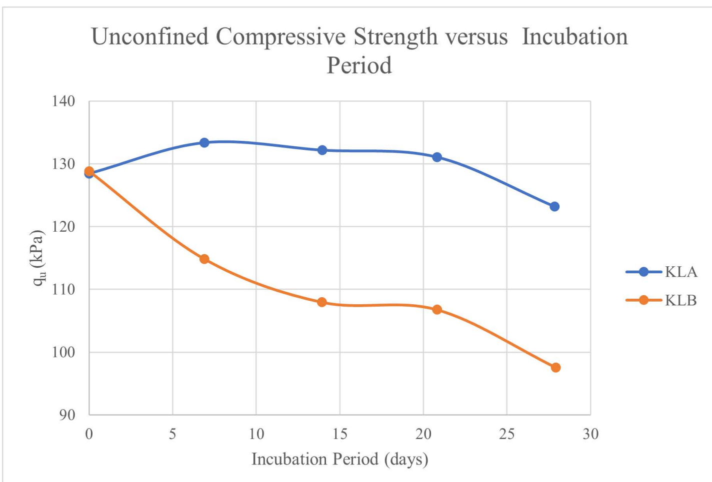


FIGURE 7. Strength Versus Incubation Period

The unconfined compressive strength of soil is directly measure for the kaolin clay soil. The higher value of compressive strength indicated better soil. The toxicity and acidic cause the reduction of the soil strength. This presence of lead attack the binding agent of the soil particle that cause the weaken the bond and decreasing the compressive strength. In addition, the soil strength also affected by the incubation period, increase of incubation period also led to reduction of the soil strength. The more incubation period gave the opportunity to the heavy react with the soil particles. The incubation period caused the soil loss the moisture content due to the reaction between the lead nitrate and the water in the soil.

PH

Table 2 below shows the effect of lead nitrate on the pH of the contaminated soil. pH is one of the important parameters to determine the toxicity level of the soil either it is acidic or alkaline. Based on the Table 2, the pH for uncontaminated sample is 5.202 at temperature 24.6 ℃. The temperature of the contaminated soil having slightly different at 7, 14 and 21 days of incubation period. The pH reducing to 5.537 after 7 days of incubation period and increase to 5.539 at 21 days of incubation period for 1000 mg/kg of Lead nitrate. The pH reading reducing after 28 day of incubation period to 4.753. For 2000 mg/kg of Lead nitrate contamination sample, the pH reading reduces from 5.321 after 7 day of incubation period to 5.304 after 14 days, 5.254 after 21 days and 4.686 after 28 days. This study reveals that the presence of heavy metal lead in soil causes the soil pH to become acidic. This observation is consistent with the findings of a previous study by Du et al. (2015), where an increase in lead concentration was found to correspond with a reduction in pH levels in contaminated soil.

When the heavy metal cation is entered into the pore water, the pH will decrease this is because the hydrogen ions cause the solution to become acidic and contribute to reduction of pH (Taheri et al. 2018). The temperature also plays an important role to determine the pH of the soil. As the temperature increase, the pH will decrease. This is because the molecular vibration increase that will result the ability of water to ionise and form more hydrogen ions. But this does not mean the soil become more acidic with increasing of temperature. Dutta & Mishra (2017) found that the decrease in pH levels varied with an increase in lead concentration in the soil. The small difference in the reading was deemed acceptable, and the influence of temperature was considered negligible.

TABLE 2. pH of soil samples

			pH	Temperature (℃)	pH	Temperature (℃)
Sample	control		1000 mg/kg		2000 mg/kg	
7 days	5.811	24.6	5.202	24.3	5.321	24.2
14 days			5.537	23.5	5.304	23.5
21 days			5.539	22.8	5.254	22.8
28 days			4.753	22.0	4.686	22.1

CONCLUSION

This study has been proven that concentration of heavy metal and incubation period influence the physical, mechanical, and chemical properties of the contaminated soil. The concentration of heavy metal and the incubation period is inversely proportional to the strength and the collapsibility soil. The increasing of heavy metal concentration will reduce the strength of contaminated soil. The increase of incubation period will lead to the reduction of soil strength due to fully reaction made by the participate between the heavy metal and the soil particles. The measure action should be taken in order remove and reduce the concentration of heavy metal contamination in soil for better future development.

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DECLARATION OF COMPETING INTEREST

None

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