Chapter in Book

Predicting Hydraulic Conductivity Landfill Soil Liner with Nomograph

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Abstract: *In the landfill, lining systems play an essential function in providing a barrier between the waste and the environment. Soil liners are used in the soil liner system to reduce leachate infiltration and prevent ground pollution. It is essential to compact the layer properly to achieve low hydraulic conductivity of 1x 10-9 m/s. The purpose of this study is to develop a nomograph in predicting hydraulic conductivity without or with minimal laboratory test in designing a modified soil liner. Geopolymer consists of palm oil boiler ash as source material and sodium hydroxide mixed with sodium silicate as an alkaline solution. Laboratory work involved physical properties tests, compaction characteristics, and hydraulic conductivity of modified mixtures. The percentage of geopolymer in the mix varies between 0%, 10%, 15%, and 20% of the dry weight of lateritic soil. The conclusion was reached based on compaction characteristics; compacted geopolymers are compatible with lateritic soils. Hydraulic conductivity of the soils was reduced by less than 1×10-9 m/s and found that laterite with a 15% of geopolymer mixture is optimum to be used as a modified soil liner in a landfill. The nomograph in predicting hydraulic conductivity, k, were developed as alternative guidelines for engineers to design landfill soil liners without conducting laboratory testing that takes a long time and can reduce the cost and time.*

Keywords: Soil liner, geopolymer, hydraulic conductivity.

1. INTRODUCTION

A landfill is a structure designed either built-in or on top of the ground to bury the waste in such a way that it will protect the environment by keeping the wastes separated from the surrounding soil, air, and groundwater. The main component of a landfill is the landfill liner or known as the soil liner. The soil liner is a barrier layer between waste and groundwater. The generation of daily waste has created a harmful liquid waste known as leachate. It is a crucial aspect in designing landfill to ensure that the leachate do not infiltrate the groundwater but drained into the collection tank for

treatment process. Liner system has great importance in preventing contact between leachate and environment. Benson (1995) stated that soil liner should have a maximum hydraulic conductivity or k-value of 1x10-9 m/s.

Traditional practices involved testing the hydraulic conductivity, k-value directly in the laboratory or on the field, which was costly and time consuming. Therefore, researcher have developed indirect methods, predicting k-value based on readily available soil properties to reduce the time and cost in conducting soil properties testing. The researchers developed models predicting k-value according to soil properties correlation with software (Alyamani et al., 1993; Shao et al., 1998; Van et al., 1989; Peter et al., 2021, William et al.,2021). Xu et al., (2013) used numerical computations and analysis to determine the volume of leachate leaks and propose measures to minimize the leakage volume and improve landfill stability. Salarashayeri et al., (2012) collected data on compacting behaviour, predictability of its characteristics by using plastic limits and emphasizing variations in compacting energy levels. Understanding the k-value of MSW and the factor's affecting k is crucial to predict hydraulic conductivity. A study is conducted to improve soil liner by adding optimum content of Geopolymer in laterite by using the nomograph to determine hydraulic conductivity, k of soil liner.

2. METHOD & MATERIAL

This study's experimental work focuses on engineering properties throughout the investigation of geopolymer as additives material in laterite for soil liner application. The primary materials used in the laboratory were boiler ash, sodium hydroxide (NaOH), and sodium silicate (Na2SiO3). The best percentage of boiler-ash geopolymer added to laterite was investigated using five different percentages, (0, 5, 10, 15, and 20%). Basic properties test conducted includes Plastic Index (PL), Liquid Limit (LL), Plasticity Index (PI), and Linear Shrinkage (LS) according to BS 1377: Part 2:1990. Compaction test using British Standard Light (BSL) according to proctor compactions test based on BS1377: Part 4: 1990: 3.3 and BS1377: Part 4: 1990: 3.5 were respectively carried out to determine the OMC and MDD of different percentages of 0, 5, 10, 15, and 20% geopolymer. The falling head were used to investigate the k-value of the samples. All collected laboratory data were analyzed, and the correlation of hydraulic conductivity was verified using the software Minitab 16. With help from this software, a hydraulic conductivity, k-model can be identified and developed. With nomographs, a new soil lining system could be designed.

3. FINDINGS

The experimental tests include the basic properties test, compaction characteristics, and hydraulic conductivity test. A nomograph was developed by Minitab 16 software to correlate and validate the results of the laboratory experiments. The aim of this research is to develop an empirical a nomograph that gives advantages in predicting the hydraulic conductivity of landfill soil liner using geopolymer.

3.1 Experimental Findings

The increase in Geopolymer content is associated with a decrease in hydraulic conductivity, leading to a significant reduction in hydraulic conductivity. Across all tests, properties were improved by up to 15% Geopolymer content. However, beyond 15% Geopolymer, no satisfactory results were observed regarding usage as a lining material. According to the correlation of k-value with laboratory

parameter, Clay, Liquid Limit (LL) and Geopolymer content gives the best correlation of P-value less 0.05 with regression coefficient, R2 more than 60%.

3.2 Nomograph in predicting k- value

This study adds valuable knowledge and landfill design to engineers by developing nomographs in predicting hydraulic conductivity. These formulas will be based on the correlation and optimum content of laterite soil with the percentage of geopolymer. With nomograph, it is possible to predict the *k*-value quickly. It can be calculated promptly, reducing the cost and time compared with conducting a laboratory test that takes a long time. In the end, geopolymer nomograph is expected to help engineers accelerate the design process of landfill systems.

4. DISCUSSION

The addition of Geopolymer as additives in laterite has significantly give positive results on soil strength in geopolymeriztion. The addition of Geopolymer turns laterite to alkaline soil and gives the effect of less soluble and does not absorb or allow leachate infiltration. The Atterberg test of Laterite-Geopolymer mix gives LL range of 39 to 48%, PL range of 29 to 34% and PI range of 10 to 19% as shown in Figure 1. According to minimum requirement based on BS 1377; 1990 test specification, the value of plasticity index ranges between 10% and 65% (10 ≤ PI ≤ 65%), and LL at ≤ 90%. Hence, the addition of Geopolymer to laterite satisfies the requirement for plasticity index and liquid limit in soil liner.

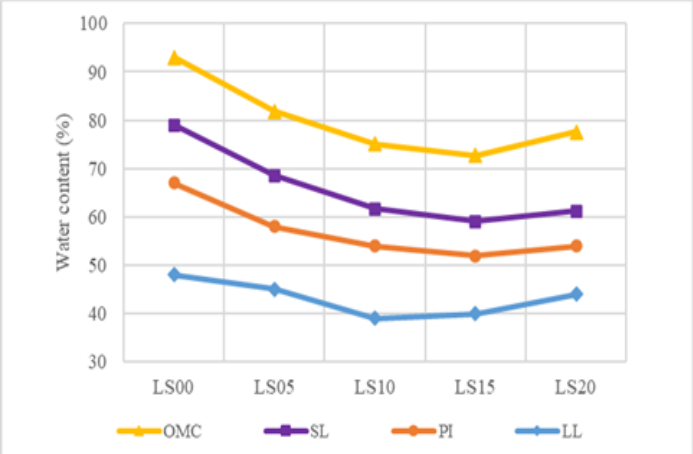

Figure 1. Atterberg and Shrinkage test value.

In compaction test, the results show that Laterite-Geopolymer mixtures have an increased MDD than plain laterite, with a corresponding reduction in the OMC as the Geopolymer content increases, up to 15% of Geopolymer. A drastic increase in MDD at 15% of Geopolymer content at 2.19 Mg/m^3 and, a reduction of OMC at 13.58% give positive results for geopolymerization reactions. The compaction characteristic of laterite with Geopolymer for all mixtures increased the MDD and decreased the OMC. Increasing dry density at low moisture content reduces soil voids, which become more accessible for the particles to move past one another during compacting forces.

Table 1. Compaction result of Laterite-Geopolymer Mix.

Sample	Moisture Content, OMC (%)	Maximum Dry Density, MDD (Mg/m^3)
LS00	14.07	1.80
LS05	13.88	1.88
LS10	13.70	1.90
LS15	13.58	2.19
LS20	16.38	1.71

Based on the result in this study, hydraulic conductivity is affected by the percentage of Geopolymer, and it can be observed that the hydraulic conductivity values were decreased with increment of Geopolymer content. t was observed that the range result for *k*-value is between 2.50 x 10^{-8} to 5.50 x 10^{-9} m/s. LS20 give the lowest value of hydraulic conductivity, *k* at 5.50 x 10^{-9} m/. Laterite containing Geopolymer can be used as alternative material in landfill liner soil. The addition of 15% Geopolymer resulted in a significant reduction in hydraulic conductivity value and meets the optimum percentage of Geopolymer suit the landfill soil liner requirement of less than 1 x 10^{-9} m/s.

In predicting *k, Log k* has a strong relationship correlation with the *P-value* of lower than α (< 0.05) including LL, C, S, and %GEO. Hence, the null hypothesis is rejected at 0.05 significant. These mentioned parameters can be a good consideration as independent variable *(x)* in finding *Log k* as predictor variable *(y)*. The correlation of *k*-value with variable with strong relationship from several parameters such as clay, sand, liquid limit, and the percentage of Geopolymer were accurately and in accordance with the statistical validity condition. According to regression data, all equations show regression coefficient R^2 *(adj)* more than 70% and nearest to 100%, with a *P-value* less than 0.05. The obtained data proved that the chosen variables are suitable for predicting k model. The null hypothesis was rejected by having the *P-value* less than 0.05, and alternative hypotheses were accepted. This study has successfully developed nomograph in predicting hydraulic conductivity, *k*-value. The data of succeed nomograph on predicted *k*-value content will simplify the landfill construction process can be used as a guideline in designing a soil liner system at landfill area.

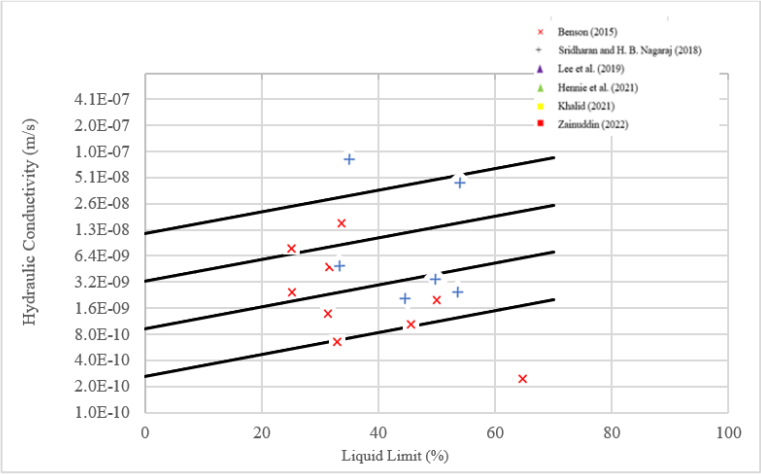

Figure 2. Nomograph in predicting *k*-value.

5. CONCLUSION

Geopolymer at different percentages has different effects on the compaction parameter and permeability of the sample, resulting in good knowledge and understanding about the properties of the product. Preliminary and main laboratory tests of the Laterite-Geopolymer mix provided a good prediction of hydraulic conductivity, *k* for soil liner application from statistical validation of physical and engineering properties. Nomograph in predicting hydraulic conductivity, *k* based on available variables (LL, Clay and Geopolymer content) were developed as alternative guidelines for engineers to design landfill soil liners without conducting laboratory testing that takes a long time and thus can reduce the cost and time.

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