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Strength of Laterite Mixed with GeoPolySoilS for Slope Cover and Protection

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Abstract: Slope stabilization or slope protection is the actions constructed on the slope or nearby areas to keep the slope safe from moving water, erosion, or the negative impacts of sudden outflow. There are a few slope stabilization methods such as geometric method, hydrological method and chemical and mechanical method that can be used to enhance the engineering properties of laterite soil. Among these methods, the chemical method was proven to be a method that is efficient to enhance the geotechnical properties of laterite soil. In this study, GeoPolySoilS was used to mixed with laterite soil to increase the strength of the soil. This study is carried out to investigate the strength of the laterite mixed with GeoPolySoilS for slope cover and protection. For the physical and mechanical properties test, laboratory experiments were conducted on natural laterite soil to determine the natural moisture content, particle size distribution, liquid limit, plastic limit, maximum dry density, optimum moisture content and unconfined compressive strength of the soil. The amount of GeoPolySoilS applied to the laterite soil sample are 0%, 5%, 8%, 10%, 12%, 15%, 18% and 20%. The results of laboratory tests show that by adding an appropriate amount of GeoPolySoilS to the soil, the stability of the slope surface increases, thus able to avoid landslides.

Keywords: Slope stabilization, laterite, GeoPolySoilS, Unconfined Compressive Strength (UCS)

1. Introduction

Malaysia is located in a tropical area that has plenty of precipitation. Malaysia is susceptible to landslides and also flooding as a result of these events (Abdullah, 2013). Due to a shortage or inadequate cover of the surface, non-vegetated or naked slopes are susceptible to erosion. In this country, the uncovered slopes, inappropriate slope management approaches, inadequate slope design, and significant rainfall may lead to slope instability that would finally lead to disasters such as landslides (Dorairaj & Osman, 2021). To minimize actual and prospective landslides caused by excavation, preventative estimates are randomly chosen during highway projects, although basic geological features of the enhanced slope are not available in order to cut costs (Dong et al., 2017). The purpose of this study is to evaluate the performance of GeoPolySoilS as a slope protection measure and cover so that the bare slopes that are non-

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*Corresponding author: dianacl@uitm.edu.my vegetated or temporary slopes without covers will be protected from rainfall infiltration and saturation of the slope face. In Malaysia, the rising number of soil erosion is a major source of concern and has become worse especially on highways and mountainous areas. This erosion causes undesirable events or disasters to occur. Erosion is a problem that requires appropriate handling. For instance, slope stabilization works are applied to mitigate the poor performance of the soil of the slope. Hence, this study will focus on slope protection and covers so that the surface of the slope is impenetrable to water and has increased shear resistance. GeoPolySoilS will be used to provide slope protection cover and resistance to infiltration, thus increases its strength to the slope.

The history of laterite soil comes from the term 'laterite' originating from the Latin word 'latere,' which indicates 'brick.' In one of his many published journals and observations during his travels all around the western coast of southern India in 1807, an English surgeon named Francis Buchanan originated the name. He connected the term with the very ferruginous clay material used during the production of earth bricks. He characterized the soil conditions as being widely spread without obvious layers, with various voids and pores, increased iron concentration, and being so loose that it could be hacked to shape with metal tools but after a while hardened as bricks when uncovered (Raychaudhuri S. P., 1980). Africa, Australasia, South and Central America, India, and South Asia are the six major areas where laterites can be found (Yamusa et al., 2017). Laterite soils are produced in place in tropical and subtropical climates from strong weathering of source material, either primary or sedimentary. The chemical modification of primary minerals, the discharge of iron and aluminium sesquioxide, the decrease of silica, and the rising supremacy of new clay materials which include smectites, allophones, halloysite, and, as weathering advances, kaolinite created from dissolved substances are all part of the weathering process (Chidozie et al., 2015).

Slope stabilization is a method or approach for preventing slope failure by enhancing resisting forces and minimizing moving forces (Mulia & Prasetyorini, 2013). Since slopes are typically a naturally occurring element of the terrain, some areas need the development of roads and buildings near them. Therefore, there are a few typically used slope stabilization methods that can be used such as geometric method, hydrological method and chemical and mechanical method (Panwar, 2019). For instance, grouting is a method of exchanging water or air in pores and fractures in a rock mass by injecting a liquid grout into the rock layers. Cement and water are mixed to make the grout. Nevertheless, sand, clay, rock flour, fly ash, as well as other materials can be used instead of cement. As an outcome, the expense of stabilizing work decreases, particularly in regions where cracks and fractures are high in volumes (Panwar, 2019).

Polyurethane resin is comprised of two liquid-based elements that are used in real situations. The application of polyurethane (PU) as a ground improvement work currently increases in demand due to its well performance in many soil improvement projects (Lat et al., 2020) Isocyanate and polyol compounds have been the most common chemicals applied. Polyol is a volumetric expanding agent that assists in the volumetric expanding of polyurethane. Furthermore, the isocyanate is used as a bonding material in the production of polyurethane. It assists in polyurethane's strength properties. The strength characteristics of the obtained resin improved as the isocyanate mixing ratio is enhanced, nevertheless, the resin consumption has risen as the expansion ratio is reduced at a set injection volume. The expansion force and resin characteristics in the compound of soil-resin can be adjusted to achieve the desired outcomes (Sabri et al., 2021). This polyurethane can be used as a soil stabilization and void filling in soil, hence enhance the soil strength (Mohamed Jais et al., 2022).

2. Methodology

The physical and mechanical properties tests were conducted to determine the properties and strength of the soil such as moisture content test, particle size distribution test, Atterberg limit test, compaction test and Unconfined Compressive Strength test. All of these tests were carried out according to the British Standard BS 1377:1990: Part 1-9. The laboratory tests were conducted at Soil Mechanics Laboratory of School of Civil Engineering, UiTM.

2.1 Sample Location

The soil sample used is a laterite soil. The laterite soil sample was collected at Sungai Buloh, Selangor as shown on the map in Figure 1 below. The soil is considered as a disturbed sample because the sample is dredged or excavated at the site before use for the test.

Fig. 1 - Location of laterite soil collected

2.2 Design Mix Configuration

The soil samples were mixed with the GeoPolySoilS and the specified amount of distilled water was added. For the design mix configuration, the dosage of GeoPolySoilS used was 5%, 8%, 10%, 12%, 15%, 18% and 20% as shown in Table 1.

Table 1 - Design mix configuration of the test

GeoPolySoilS added (%)	Soil Sample	Testing laboratory
0	Original laterite soil	➢ Natural moisture content ➢ pH test ➢ Particle size distribution (Sieving and Hydrometer test) ➢ Atterberg limit ➢ Standard Proctor test ➢ Unconfined Compression Strength (UCS) test
5	+ laterite soil	➢ Unconfined Compression Strength (UCS) test
8		
10		
12		
15		
18		
20		

3. Results and Discussion

3.1 Physical Properties of Soil

Table 2 shows the properties of natural laterite soil. According to the Plasticity Chart British Soil Classification System (BS5930:1981), the soil was categorized as clay of intermediate plasticity (CI).

Table 2 - Summary of natural laterite soil

Properties		Values
Natural moisture content	%	18.57
Particle Size Distribution:		
i) Gravel	%	0.60
ii) Sand	%	1.40
iii) Silt	%	94.91
iv) Clay	%	2.91
Liquid limit, LL	%	43.60

Plastic limit, PL	%	25.78
Plasticity Index, Ip	%	17.82
Maximum Dry Density (MDD)	Mg/m3	1.62
Optimum Moisture Content (OMC)	%	25.92
Classification		CI

3.2 pH

The average of pH value obtained is 4.35 as shown in Table 3. This indicated that the laterite soil is acidic due to the value of pH being less than 7. Leaching of the soil results from the formation of laterite soil, which is characterized by high temperatures, intense rainfall and alternating wet and dry phases. Leaching occurs when the minerals in the source rock are dissolved by acid. Throughout the process, basic salts that are soluble at the surface, such as those of Ca, Mg, K, and Na, are again washed away by stormwater runoff, leaving behind insoluble acidic residues that are primarily made of iron, silicon, and aluminium oxides and silicates. These salts react in an acidic approach. Thus, the soils are acidic.

Table 3 - pH reading of this study

pH reading	
1	4.27
2	4.32
3	4.47
Average:	**4.35**

3.3 Atterberg Limit

Based on Table 4 shows the result obtained for the Atterberg limit test. The classification of the soil according to the Plasticity Chart British Soil Classification System (BS5930:1981) is Clay of intermediate plasticity (CI).

Table 4 - Results of Atterberg Limit test of this study

Properties	**Values**
Liquid limit, LL (%)	43.60
Plastic limit, PL (%)	25.78
Plasticity Index I_P (%)	17.82
	CI - Clay of Intermediate plasticity

3.4 Compaction Test

The graph in Figure 2 shows the maximum dry density (MDD) and optimum moisture content (OMC) of the soil. The maximum point of the compaction curve can be determined to obtain the maximum dry density and optimum moisture content values used in this test. The value of the Maximum Dry Density (MDD) is 1.62 Mg/m3 while Optimum Moisture Content (OMC) is 25.92 %. Findings from this research is in agreement with the previous research by Rosli et al. (2017).

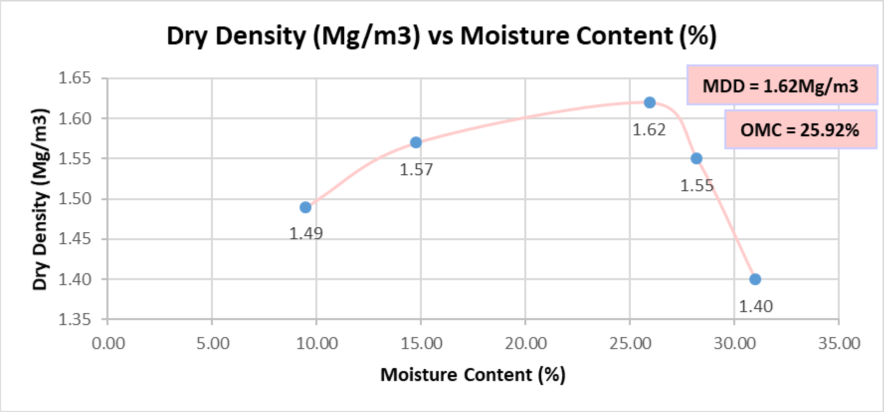

Fig. 2 - Graph of compaction test

3.5 Unconfined Compressive Strength Test

Figure 3 presents the graph of axial stress versus axial strain for the Unconfined Compression Strength (UCS) laboratory test after curing for seven days. The graph shows the curve for eight different dosages of GeoPolySoilS applied as a stabilizer agent to the soil sample which are 0%, 5%, 8%, 10%, 12%, 15%, 18% and 20% respectively. Each curve hits its maximum before beginning to descend owing to the soil sample's fragile structure. From the graph, the axial strain increases with the increase of the axial stress until its maximum value. From this stress-strain curve, the maximum value of Unconfined Compressive Strength (UCS) can be determined. The axial stress increases as the dosage of GeoPolySoilS added to the soil sample ranging from 0% to 18% and begin to drop as the soil sample start to brittle.

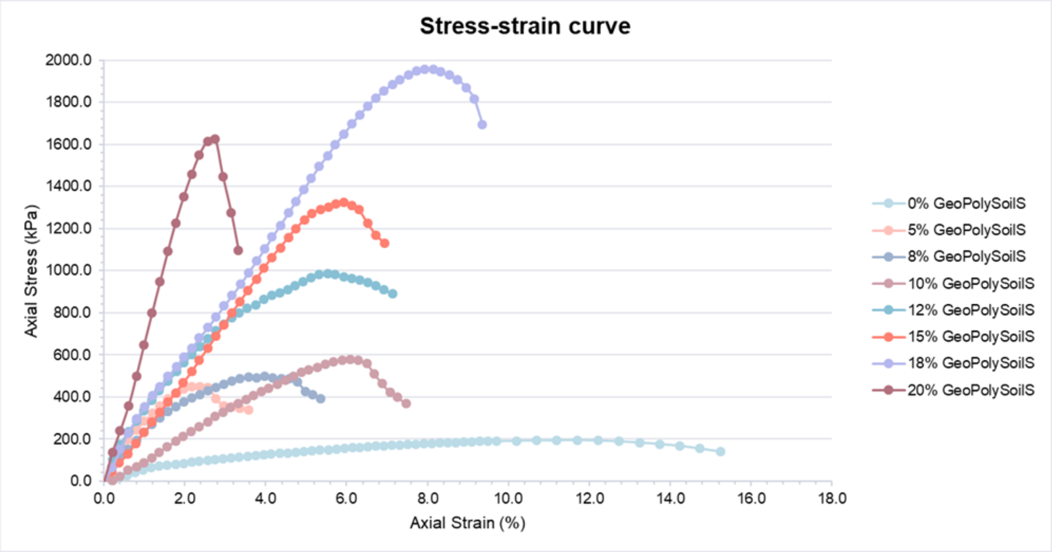

Fig. 3 - Stress-strain curve of this study

The Unconfined Compressive Strength (UCS) test was carried out to determine the strength of the soil that was mixed with the GeoPolySoilS. The maximum axial stress at failure is known as the Unconfined Compressive Strength (UCS) value. This test was conducted for 24 samples whereby 3 samples without GeoPolySoilS were control samples whilst 21 samples were mixed with different dosages of GeoPolySoilS (5%, 8%, 10%, 12%, 15%, 18%, and 20%). The modified soil was curing for 7 days.

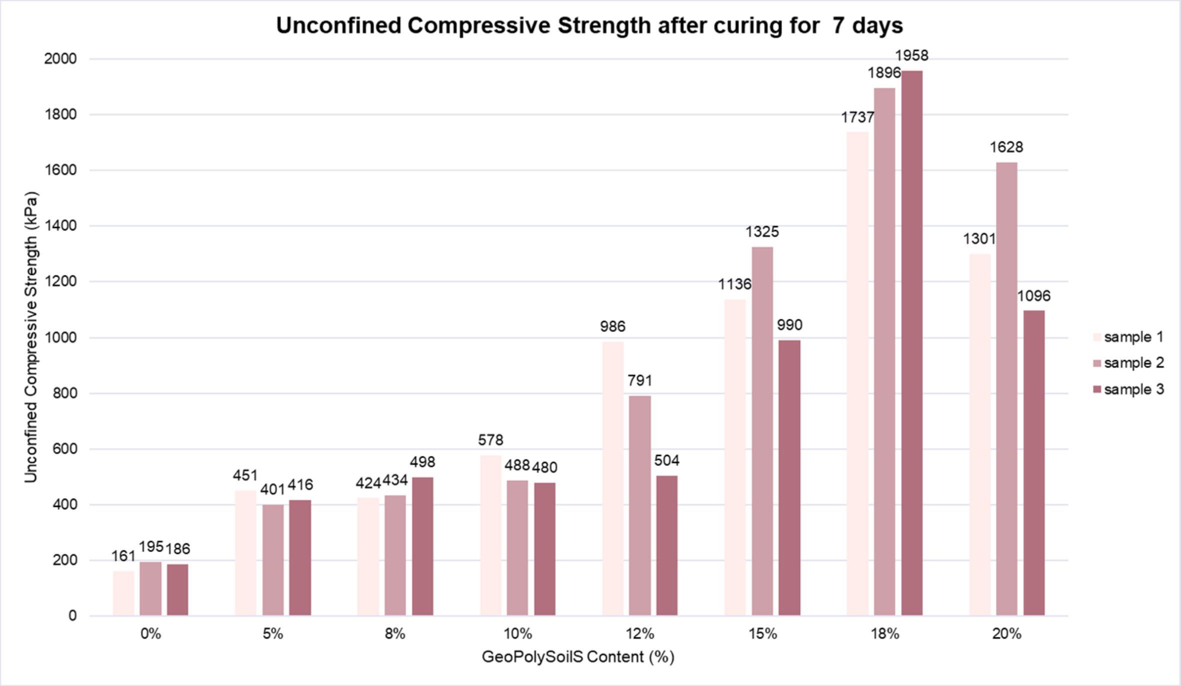

Fig. 4 - Unconfined Compression Strength at different percentage of GeoPolySoilS

This bar chart is produced to determine the effectiveness of GeoPolySoilS added to the soil. In general, it is observed that the value of the UCS increased when the amount of GeoPolySoilS percentage increased. It is also observed that the percentage of GeoPolySoilS increased up to 18% with the UCS value of 1958 kPa, however with a further increase in the percentage of GeoPolySoilS to 20%, the value of the UCS slightly decreased which is 1628 kPa. The 20% dosage is not economical because the cost of stabilization is expensive and adding a 20% dosage of GePolySoilS, reduces the soil strength. Hence, this concludes that 18% of GeoPolySoilS content is the optimum dosage to laterite soil for slope protection and cover. In comparison to the JKR Specification Standard (Malaysia Public Work Department, 2017) which is stated that for the slope, the value of Unconfined Compressive Strength must be 300 kPa or higher. The value of UCS for 5% to 20% dosage of GeoPolySoilS is higher than 300 kPa, except for 0% dosage of GeoPolySoilS. Hence, this modified soil is strong enough for slope protection although used at 5%. However, for the optimum dosage of soil which is 18% to the laterite soil, the slope surface will be more strengthened. Hence, this enables to enhance the surface cover of the slope.

When estimating soil settling and performing elastic deformation analysis, the elastic modulus is frequently used (Somwanshi, 2020). From Figure 5, it is significantly shown that 8% GeoPolySoilS have higher values of Elastic modulus compared to 0% and 5%. However, at 20% GeoPolySoilS, the elastic modulus is higher than other although the value is not consistent on that percentage followed by 15%, 12%, 10%, 8%, 18%, 5%, and lastly 0% dosage of GeoPolySoilS. To conclude, at 15% of GeoPolySoilS content, the values of Young’s modulus are higher than other samples. This indicated that when the laterite soil is categorized as clay of intermediate plasticity, the sample of 20% has the highest stiffness (Young et al., 2013).

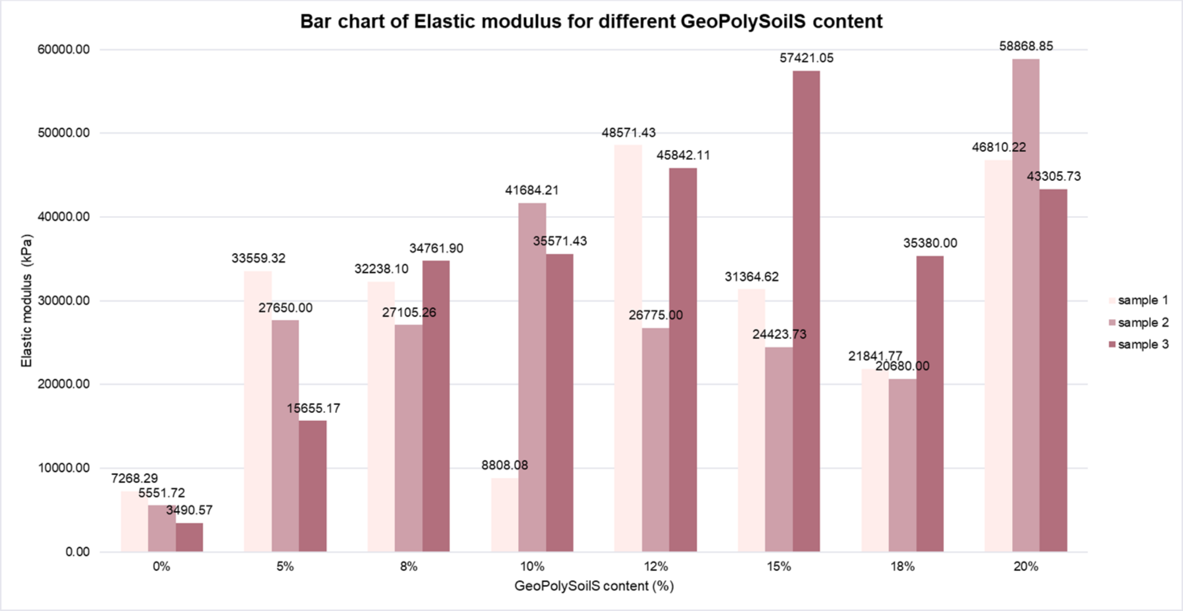

Fig. 5 - Bar chart of Elastic modulus for different GeoPolySoilS content

4. Conclusion

In this research paper, the addition of GeoPolySoilS is able to improve the strength of the laterite soil prior to its great behavior. The optimum dosage of GeoPolySoilS mixed with the laterite soil is recognized at 18% as it has a higher value of unconfined compressive strength which is 1958 kPa, exceeding the strength requirements by the Malaysia Public Work Department (2017) which stated for Unconfined Compression Strength test curing for 7 days must be exceeded 300 kPa for the slope surface. Therefore, it is proved that the laterite soil without the addition of a stabilization agent is not strong enough. Nonetheless, by adding an appropriate amount of GeoPolySoilS to the soil, the stability of the slope surface increases thus able to avoid landslides. It is essentially possible to utilize GeoPolySoilS to stabilize laterite soil in the construction industries nowadays as the GeoPolySoilS agent is quite easy to apply and just needs to spray to the slope surface.

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