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Peat Ground Improvement with GeoPolySoilS

Ismacahyadi Bagus Mohamed Jais[a,b], Muhammad Luqmanul Haqim Mustafa Kamal[a] & Diana Che Lat[c*]

[a]*School of Civil Engineering, College of Engineering, UiTM Selangor, 40450, Shah Alam, Selangor, Malaysia*

[b]*Institute for Infrastructure Engineering and Sustainable Management, School of Civil Engineering, College of Engineering, UiTM Selangor, 40450, Shah Alam, Selangor, Malaysia*

[c]*School of Civil Engineering, College of Engineering, UiTM Pasir Gudang, 81750, Masai, Johor, Malaysia*

[*]*Corresponding author: dianacl@uitm.edu.my*

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ABSTRACT

Peat soil is frequently seen as a soil foundation concern which normally required soil stabilization work. This study is conducted to assess the strength of peat soil mixed with GeoPolySoilS as a proposed ground improvement work for peat soil in Kampung Johan Setia in Klang Selangor, Malaysia. In order to look into the strength improvement of this peat soil, laboratory tests were conducted namely Unconfined Compressive Strength Test (UCT) and Calfornia Bearing Ratio Test (CBR). The highest strength of UCT for the uncured soils with 14% GeoPolySoilS is 161 kPa whilst for the sample that was cured for 7,14,28 and 50 days, the highest value of UCT with 20% GeoPolySoilS are 58.08 kPa,61.66 kPa, 95.62 kPa and 80.04 kPa respectively. For the CBR value, the highest top layer value is 8.12% for peat soil mixed with 14% GeoPolySoilS whilst the highest value for the bottom layer is 62.25% for unsoaked CBR. For soaked CBR, the highest top layer value is 5.82% for 20% GeoPolySoilS and the highest value for bottom layer is 43.07%. The strength of the modified peat increased with the increased of curing time and the percentage of GeoPolySoilS

Keywords: Peat; ground improvement; GeopolySoilS; CBR test; Compressive strength

INTRODUCTION

Malaysia is a tropical country having the world's sixth-largest peat reservoirs. The peatland in this region is mostly used for plantations (palm oil, pineapple, and banana), cultivation land, and nominal economic (Kolay and Pui, 2010; Mohamad, 2015; Wahab, 2020). Peatland is one of the most critical soil types in Malaysia, accounting for around 3.0 million hectares (8.0 percent) of the country's total land area. Mostly, peatlands are found in Peninsular Malaysia, while Sarawak states cover about 13.1% or 1.65 million hectares of peatland, which is considered substantial in the region (Moayedi and Nazir, 2018). Due to the extreme softness, unconsolidated, and the low shear strength, stiffness, and high-water content in peat soils, this type of soil is not usually used in road construction due to excessive and long-term settlement during or after the construction and ultimately results in time and cost overruns in construction projects (Wahab et al. 2021).

The method of soil stabilization divided into two parts which are mechanical stabilization and chemical stabilization. Mechanical stabilization is the method of modifying the soil gradation in order to increase its quality by physical process (Afrin, 2017). Chemical stabilization typically consists of chemical substances or mixtures to bind soil particles altogether, and the alterations in soil characteristics are usually more complicated than mechanical alteration (Tan et al. 2020). Among the different methods of soil improvement, chemical stabilization, using chemicals to boost soil strength properties and weight capacity while minimizing settlement is currently becoming a more popular alternative. Mixing cement, lime, liquid polymers, resins, acids, silicates, and lignin derivatives in different combination seems to be more typical instead of using other chemical components (Marto et al. 2013; Razali et al. 2023).

The polyurethane can be used as a soil stabilization to prevent void filling in soil and hence enhance the soil's strength. Polyurethane resins have low viscosity, excellent adhesion, high durability, polymerized in the presence of water and are also impermeable. Polyuretahane resins can be either rigid or flexible. Stabilizing the marine clay with the polyurethane improved the shear strength of the marine clay from 75 kpa to 250 kpa and further reduces the cumulative strain of the soil from 5.18% to 2.92% which correspond to improvement by 230% increase in shear strength and 77% decrease in cumulative strain (Samailah Saleh, 2018) Utilization of polyurethanes as a stabilization material for marine clay is technically viable mainly due to its short gelling and hardening time will make it an excellent and quick improvement method, speedy construction and handy for remedial works (Mahamed Jais, 2017; Samailah Saleh, 2018; Lat et al. 2022)

GeoPolySoil is a polyurethane chemical stabilizer used in this study to improve the properties of peat soils. GeoPolysoilS comprised of two liquid-based elements, isocyanate and polyol compounds that have been the most common chemicals applied. Polyol is a volumetric expanding agent that assists in the volumetric expanding of polyurethane (Buzzi et al. 2008). Furthermore, the isocyanate is used as a bonding material in the production of polyurethane and 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 research was carried out in Malaysia, and the soil employed was peat soil blended with GeoPolySoilS. The California Bearing Ratio (CBR) test is performed in construction materials laboratories to evaluate the strength of soil subgrades and base course materials. CBR strength is an essential soil property for designing flexible pavements and air field runway (Muthu et al. 2021). If the CBR value of the subgrade is less than 10, the subbase will deflect under traffic loads, causing pavement deterioration. Therefore, it is crucial to study the strength and CBR of the peat soil that is mixed with GeoPolySoilS. The objective for this study is to determine the physical and mechanical properties of the peat soil. Second is to find the optimum dosage of GeoPolysoilS to improve peat soil. Finally, is to evaluate the strength and CBR of the modified soil.

MATERIALS AND METHOD

The BS1377: Method of Test for Soils for Civil Engineering Purpose (1990), BS 1377-2:1990, BS 1377-2:1990, ASTM D2974-07a, and BS 1377-7:1990 were referred for all tests carried out for this study. The peat soil sample was obtained from Kampung Johan Setia in Klang Selangor, Malaysia. The samples were taken with a thin wall sampler for undisturbed soil and with a hand auger for disturbed soil. To maintain the moisture content of undisturbed samples, the entire sample was wrapped in plastic after collection. To complete the study and evaluate the strength of peat before and after the addition of GeoPolysoilS, laboratory testing is carried out to determine peat behaviour. Physical qualities and engineering properties are split into two groups in laboratory tests, as illustrated in Table 1. The samples were compacted in a 50 mm × 100 mm mould that allowed for continual compaction with a tamping rod. Because the soil in its natural state is only loosely connected, it needs to be compacted in order to increase its bearing capacity (Hussain & Dash, 2016). The compaction test shows the relationship between the dry density and the amount of water in a soil sample. The samples were then cured in a water bath for 0 days, 7 days, 14 days, 28 days, and 56 days to mimic the condition of peat below the water table before being tested for UCT and CBR. Bearing capacity of soil can be determined using California bearing ratio (CBR) test (Bharath et al. 2021). The UCT was performed for modified peat with GeoPolySoilS content of 10, 14, 16, and 20% (Akol, 2012; Ashraf, 2018) after the sample was cured for 7, 14, 28, and 56 days. Whilst CBR test was carried out for modified peat with the same percentage of PolySoilS as UCT for soaked and unsoaked conditions.

TABLE 1. Standard references for laboratory test

Test	Standard References	Purpose
Moisture content	BS 1377-2:1990	Determination of moisture content of a specimen of soil as a percentage of its dry mass.
Specific Gravity	BS 1377-2:1990	Determination of the density of the soil solids

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Organic Content	ASTM D2974-07a	Determination of the percentage by dry mass of organic matter present in soil.
	Engineering Properties Test	
Unconfined Compression test (UCT)	BS 1377-7:1990	Determination of unconfined compressive strength
California Bearing Ratio (CBR)	BS1377-4:1990	Determination the bearing capacity of soil.

RESULTS AND DISCUSSION

PHYSICAL PROPERTIES

The peat from Kampung Johan Setia is categorized as hemic based on the results of the physical characteristics tests because its fiber content is 48.45 percent, which is semi-fibrous and intermediately deteriorated, and its organic content is 88.21 percent. The specific gravity of 1.33 is low due to the high moisture content, which is 590.50 percent. The peat that was gathered had a pH of 3, which is quite acidic. Table 2 summarizes the physical properties of peat in Kampung Johan Setia, Klang, Selangor.

TABLE 2. Physical properties of peat in Kampung Johan Setia, Klang, Selangor

Properties	Value
Moisture Content (%)	590.50
Specific Gravity (Gs)	1.33
Organic Content (%)	88.21
Fibre Content (%)	48.45
pH value	3
Category	hemic

UNCONFINED COMPRESSIVE STRENGTH

Unconfined Compressive Strength Test (UCT) was performed on uncured natural and stabilised peat samples. After combining with GeoPolysoilS, the stress-strain relationship was immediately assessed. The stress-strain connection was examined right away after the peat soil being mixed with GeoPolysoilS, as shown in Figure 1. The natural peat has a maximum compressive strength of 13 kPa. The compressive strength of stabilised peat reaches a maximum at a GeoPolysoilS concentration of 14% which is 161 kPa and the minimum compressive strength at a GeoPolysoilS concentration of 10% which happen to be 117kPa. The UCT was performed for modified peat with GeoPolysoilS content of 10, 14, 16, and 20% after the sample was cured for 7, 14, 28, and 56 days. Figure 2 shows the stress-strain curve when it is tested after 7 days curing. At 7 days after curing, the compressive strength of modified peat peaks at 20% GeoPolysoilS content, which is 58.08 kPa, and the lowest point is at 10% GeoPolysoilS concentration, which is only 7.36 kPa. Figure 3 shows the stress-strain curve when it is tested after 14 days curing. At days 14 after curing, the compressive strength of this modified peat reaches 61.66 kPa at 20% GeoPolysoilS content, while the lowest value is 10% GeoPolysoilS concentration (11.63 kPa). Figure 4 shows the stress-strain curve of the sample when it is tested after 28 days curing. At 28 days after curing, the compressive strength of modified peat reaches 95.62 kPa at 20% GeoPolysoilS content, while the number drops to 22.75 kPa at 10% GeoPolysoilS content. Figure 5 shows the stress-strain curve of the sample when it is tested after 56 days of curing. At 56 days after curing, the compressive strength of modified peat reaches 80.04 kPa at 20% GeoPolysoilS content, while the lowest value is still at 10% GeoPolysoilS content which is 32.68 kPa. The results reveal in Figure 6 shows that natural peat has a low unconfined compressive strength of 13 kPa. Based on research conducted by (Hashim & Islam, 2008), the unconfined compressive strength of typical peat is even lower which is 6.9 kPa. As a result, natural peat before modification with GeoPolysoilS has very low values compared to modified peat and the peak strength increases with the increased percentage of GeoPolysoilS.

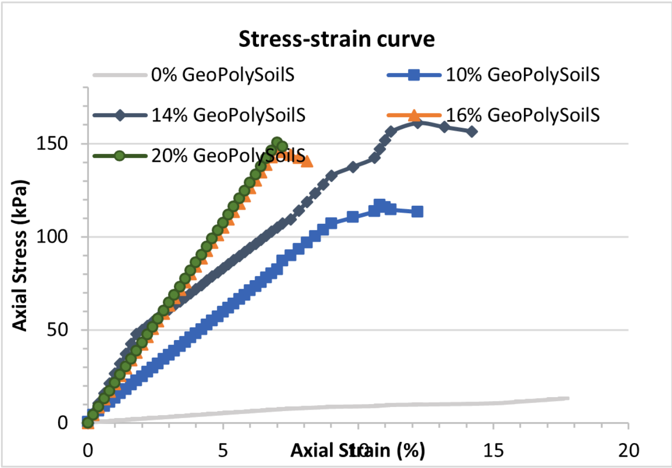

FIGURE 1. Stress strain response of natural and modified peat soil immediately after mixing

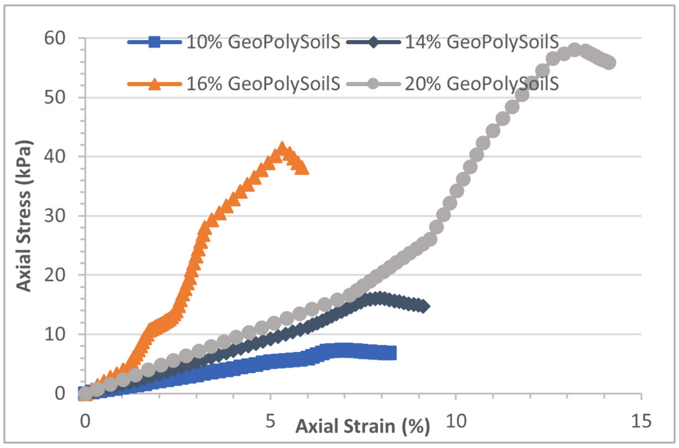

FIGURE 2. Stress strain response of modified peat after 7 days curing

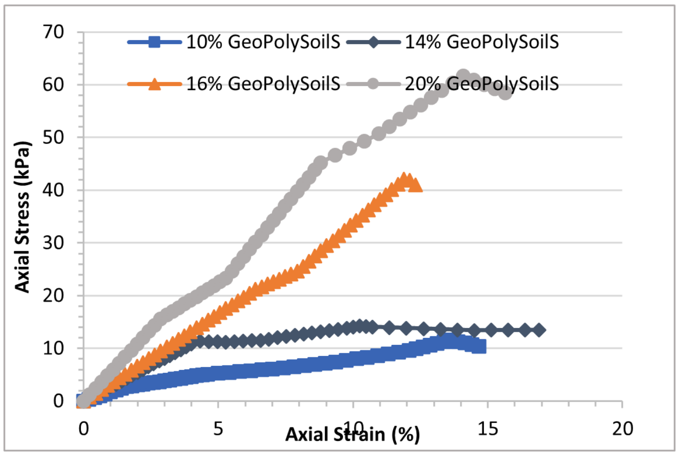

FIGURE 3. Stress strain response of modified peat soil after 14 days curing

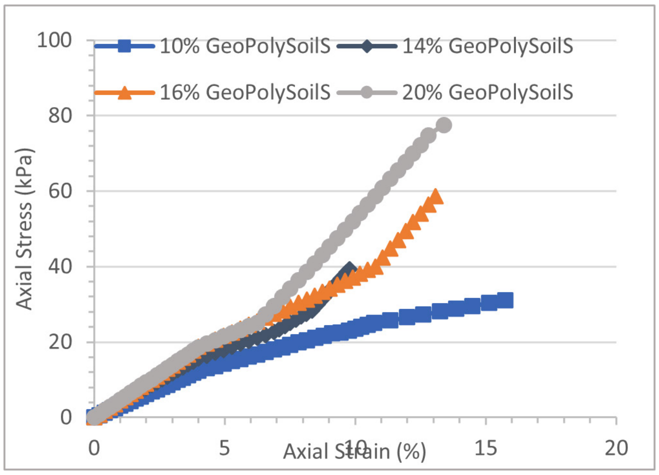

FIGURE 4. Stress strain response of modified peat after 28 days curing

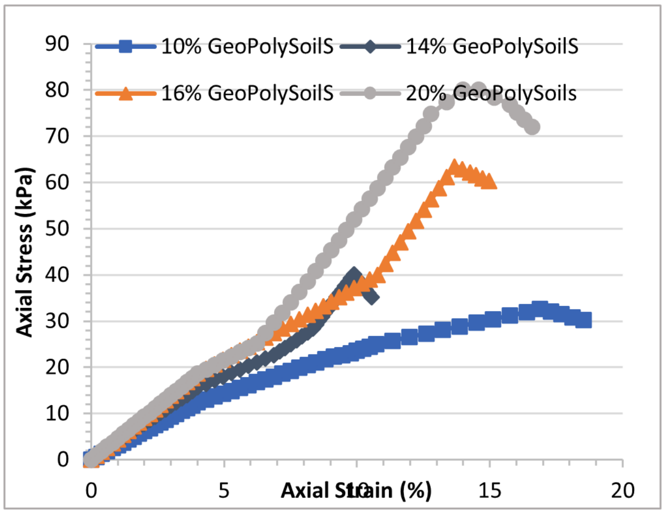

FIGURE 5. Stress strain response of modified peat after 56 days curing

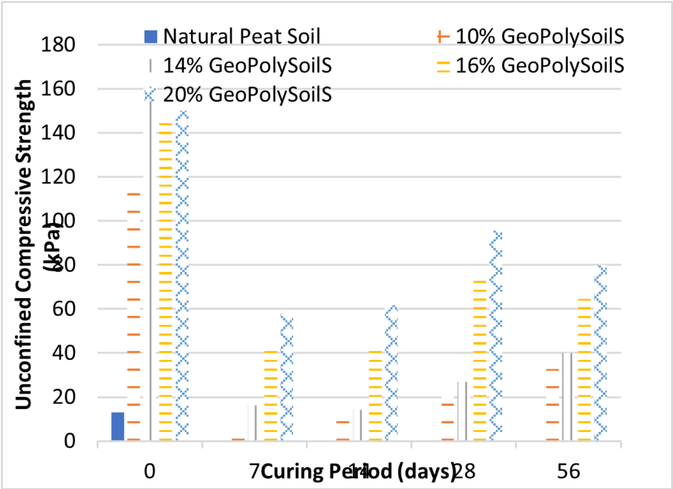

FIGURE 6. Summarized of UCT test results on natural and improved peat.

UNDRAINED SHEAR STRENGTH

From the result shown in Figure 7, it is observed that for the sample without curing, the undrained shear strength, Cu increased when the GeoPolySoilS content increased which happen to be 58.57 kPa, 80.5 kPa,73.5 kPa, and 75 kPa respectively. However, after letting the sample cured to 56 days, there is a significant reduction in the undrained shear strength value. It is obvious that the chemical composition of GeoPolySoilS played an important role in the strength enhancement. The moisture content of stabilized peat decreases because the air void of natural peat was filled up by small particles of the admixture material (Kolay and Pui, 2010). There has been a noticeable trend of stabilised peat strength decreasing from the beginning of the curing days. This is because the samples have become weaker as a result of being immersed in a water bath throughout the curing process. The presence of high ground water levels in peatland areas needs to be handled and simulated appropriately, even though the samples without curing exhibit enhanced modified strength. The hydration process is still incomplete during short curing duration (Md. Yusof et al. 2015). Therefore, a longer curing time is required to encourage the reaction of the geopolymer stabiliser and achieve a higher strength.

Hence, at 28 days of curing period, there is an increment in strength of the soil especially for peat that has been modified with 16% GeoPolySoilS and 20% GeoPolySoilS which are 31.4 kPa and 33.96 kPa respectively. At 56 days after curing, the sample shows an increment in strength for the sample with 10% GeoPolySoilS and 14% GeoPolySoils which are 9.96 kPa and 13.26 kPa respectively. Meanwhile the sample with 16% and 20% GeoPolySoilS shows a decrement in strength which are 10 kPa and 15.58 kPa respectively.

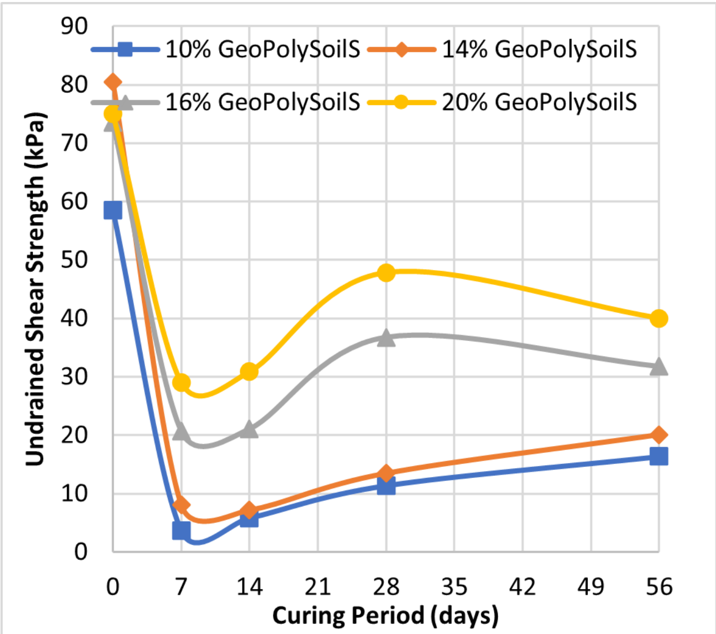

FIGURE 7. Undrained shear strength test results for peat mixed with different percentage of GeoPolysoilS

CALIFORNIA BEARING RATIO (CBR)

As shown in Figure 8, for the unsoaked CBR, the value of CBR for top layer was at the highest when the amount of GeoPolysoilS was at 14% and lowest when the mixture is at 10% at which 8.12 % and 1.09% respectively. However, after leaving the sample soaked for 4 days in water bath, the sample showed a reduction in the CBR value. The sample reduced to almost half from their unsoaked sample. The CBR value for the top layer was very low which not even achieved more than 13%. However, the bottom layer for the sample reached up to 50% to 60% CBR value as shown in Figure 9. One of the main reasons of this occurrence was due to the fact that the segregation of material at the bottom layer. This happened due to the sample was not mixed homogeneously.

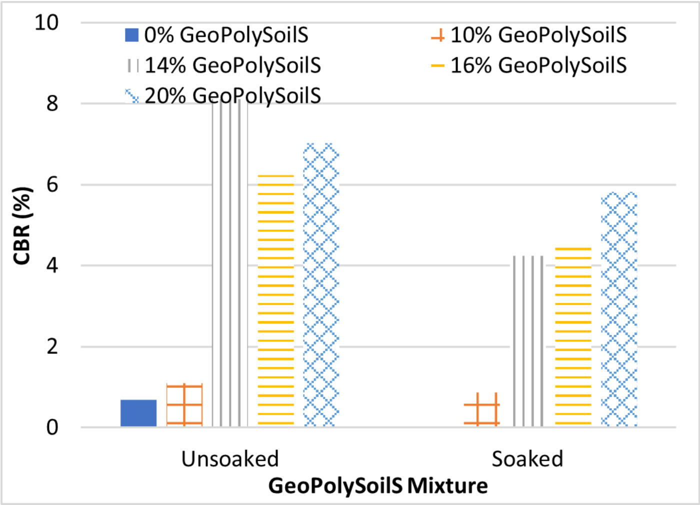

FIGURE 8. CBR value versus GeoPolysoilS mixture (Top)

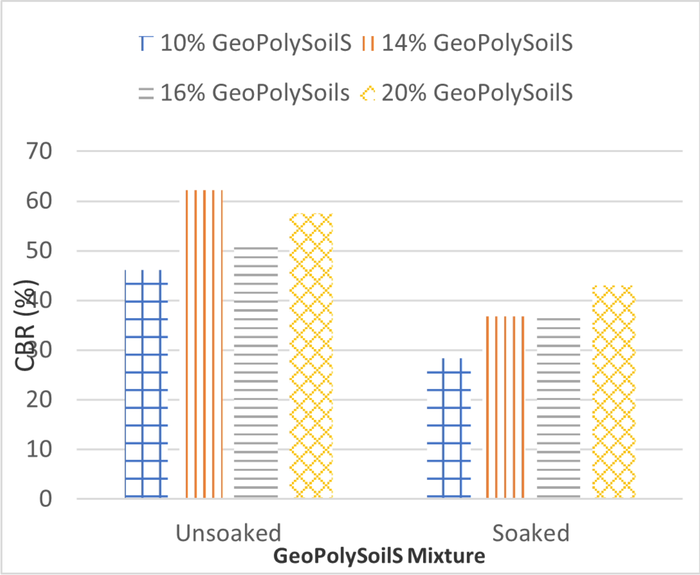

FIGURE 9. CBR value versus GeoPolysoilS mixture (Bottom)

CONCLUSION

This research was designed to determine the strength of modified peat soils with GeoPolySoilS as a ground improvement work, hence evaluate the strength for both natural and modified engineering properties of the peat. It can be concluded that:

1. The soil sample was proven to be organic peat based on the physical characteristics of peat, including its organic content, moisture content, fibre content, specific gravity, and pH test. UCT have been conducted to determine the compressive strength and it shows that natural peat has a low compressive strength of 13 kPa.
2. Peat soils was modified with various GeoPolySoilS percentage (10%, 14%, 16%, and 20%), and it showed the increased in strength. Immediately after mixing, the highest value of undrained shear strength for the modified peat with 14% GeoPolySoilS was 80.5 kPa while the lowest was 58.57 kPa at 10% GeoPolySoilS.
3. The strength of the modified peat increased with the increased of curing time and the percentage of GeoPolySoilS. Hence, the longer the curing period is, the peat getting more stable due to pozzolanic reaction and hydration process.

4. The CBR value of the modified soil was also increased but not to our expectation. It was due to the fact that the mixture is not homogeneous enough that caused the sample to have a segregation of the material at the bottom layer.

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DECLARATION OF COMPETING INTEREST

None

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