Improvement of engineering properties of liquefied soil using Bio-VegeGrout

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Abstract. Lab tests were carried out in order to analyze and investigate the liquefaction behavior of marine deposit soil which was placed in the region of LCCT, Sepang. The soil was found exposed to liquefaction. Step to improvise the soil was to inject Biovege grout into the soil sample. Soil sample was prepared with three different grout amount, 10%, 25% and 50%. The relation between percentage of Biovege grout injected and soil improvement were observed and recorded. The void ratio and the permeability of the soil sample decreased with increasing grout percentage. The soil becomes stiffer as the amount of grout used increase. The results obtained indicate, higher amount of grout injection reflects better soil improvement in term of cohesion, friction angle, shear stress and void ratio. The Biovege grout increases the resistance of soil against liquefaction

1. Introduction
Soil liquefaction occurs when the soil goes sudden massive loading which eventually forces the soil to flow. This phenomenon will eventually lead to instability of soil and causes fatal damage to human lives as well as properties. A lot of researches were conducted to develop sustainable or green materials as well as the methodology in hope of reducing carbon foot prints. As for soil improvement, research on strengthening soil using microorganisms (i.e. bacteria) has been the focus as it has very low carbon footprint while improving the properties of weak soil with minimal cost. Van Paassen (2009) [4] proved that bacteria can be used as the source to carbonate precipitation, which changes the mechanical properties of soil. Whilst, the winner of 2010 Next Generation Award [3], G.K. Dosier of American University of Sharjah, UAE found that the mixture of common bacteria, calcium chloride and urea could transform sand into sandstone using Microbial Induced Carbonate Precipitation (MICP) technique. This technique uses microbes to produce links or bridges between soil particles a chain of chemical reactions. Meanwhile another study conducted by H. Kamarudin (2012) [1] shows that bacteria to form carbon precipitation could also be derived from vegeTables waste also known as VegeGrout has significant impacts on the properties of remoulded soil samples. Therefore, this study was conducted to evaluate the improvement of engineering properties of liquefied soil using VegeGrout.
2. Soil Modification

2.1 Bio-Mediated Soil Improvement
The Bio-Vege Grout contains microorganism which precipitate the calcite or calcium carbonate (CaCO$_3$) around each and every particle of the soil by going through some chemical reactions. Thus this method is economical and at the same time has low impact on enviroment. Bacteria and fungi are most commonly found in the waste as the waste starts to decompose. This formation of calcite on the grain will increase the stiffness and the cohesiveness among particles. Thin layer of calcite will form on the particle and the gap and voids between the particles which water can fill during an earthquake leading to liquefaction. Indirectly the strength of the soil will increase to withstand the loading.

3. Methodology

3.1 Soil Sampling and Preparation
Soil samples for this study were taken from site nearby Low Cost Carriage Terminal (LCCT), Sepang, Selangor. According to the site investigation report these soils are susceptible to liquefaction phenomenon which has SPT N value less than 10. Both disturbed and undisturbed samples were taken for laboratory testing. All samples were tested to obtain their index and mechanical properties.

3.2 Preparation of Bio-Vegegrout
Four types of vegeTable wastes namely water spinach, cucumber, spinach and long beans were collected from Pasar Borong Selangor to produce five different Bio-VegeGrout. These vegeTable wastes with mass of five kg each were stored in five different air tight containers for four weeks. As the results, five different VegeGrout liquid were produced i.e. spinach, long beans, water spinach, cucumber and mix vegeTables. It is important to ensure the liquid produced from vegeTable wastes is free from any impurities and dirt, therefore it is required to filter the liquid before applying it to the soil.

3.3 Application of Bio-Vegegrout Onto the Soil
In order to study the performance of Bio-VegeGrout on soils, three samples weigh 2000 grams with different amount i.e. 10%, 25% and 50% of Bio-VegeGrout were injected and incubated for four weeks. The percentage of Bio-VegeGrout used was calculated based on the mass of soil used. To ensure the Bio-VegeGrout is spreading equally throughout the soil layers, the soils were split into three layers with 6 cm in depth and Bio-VegeGrout liquid was equally injected through 1.5 cm spacing drinking straw that penetrate the soil layers. Details of the test sample set up are shown in Figure 1.

![Figure 1. Schematic diagram of test sample](image-url)
3.4 Index and Engineering Properties

A series of laboratory testing was conducted in determining the index and engineering properties of the soil. The tests consist of initial moisture content, sieve analysis, shear strength namely Unconsolidated Undrained triaxial testing (UU), consolidation and permeability tests. A series of testing to obtain before and after treatment with Bio-VegeGrout were recorded.

4. Result Analysis and Discussion

From the laboratory testing, index properties of the soil are considered as slightly silty gravelly SAND with 9.5% and 2.2 as its moisture content and specific gravity respectively. The result obtained from the stress strain graphs in Figure 2 proves that the injection of Bio-VegeGrout has increased the shear stress of the soil. The Figure 2 indicates the effect of grout on the soil stress under three different confining pressures. The amount of grout used reflects the concentration of bacteria presence, thus more bacteria can produce a higher amount of calcium carbonate precipitation. With the addition of 50% grout, the soil is able to withstand twice the load of the actual soil can support. Consequently, the addition of Bio-VegeGrout will reduce the exposure of soil to liquefaction.

![Figure 2. Comparison of stress strain relationship of treated samples](image)

From the laboratory testing and result analysis the shear strength parameters are increased by at least 7% for friction angle and more than 100% for cohesion value after 4 weeks of curing period which eventually increase the shear strength of the soil and its bearing capacity. Other engineering properties such as permeability and consolidation value are increased. The result shows that the permeability value of the soil, \( k \) reduce as the percentage of Bio-VegeGrout increase. This is due to the process of calcite precipitation which reduces the drainage condition of the soil. The grout has a very low viscosity and small size of bacteria cell which allows the grout to seep through low permeability soil and penetrate into the voids by the gravity force only. This situation takes place as the voids in the soil are being filled by the calcium carbonate leaving less space for the water to flow through the soil. In real life condition, biografts are used for soil cementation and also for leakage control or prevent seepage of toxic pollutants into permeable soil (Ivan B. Gratchev, 2006) [2]. Consequently results in reduction of void ratio of the soil which can be advantages in term of avoiding any harmful pollutants to seep into the soil and it can be used to avoid landslides which are triggered by high level of ground water Table. Moreover, results for consolidation test indicate that the rate of consolidation becomes slower as the permeability of soil decreases. This relation can be used to reduce the amount of soil settlement for building construction. A summary of properties of soil before and after the injection of the Bio-VegeGrout is shown in Table 1.
Table 1. Summary of engineering properties of soil using Bio-VegeGrout

| Parameter                        | Amount of Bio-VegeGrout (%) |
|----------------------------------|-----------------------------|
|                                  | 0% | 10% | 25% | 50% |
| Cohesion, c (kN/m²)              | 15 | 38  | 53  | 61  |
| Friction angle, φ (°)            | 26 | 28  | 31  | 38  |
| Coefficient of Permeability, k (m/s) | 3.36x10⁻⁶ | 1.1x10⁻⁶ | 5.7x10⁻⁷ | 2.99x10⁻⁷ |
| Initial Void Ratio               | 0.33 | 0.3 | 0.26 | 0.19 |

5. Conclusion and Recommendation
As a conclusion, the application of Bio-VegeGrout via injection does improve the engineering properties of the soil with the increment of Bio-VegeGrout percentage. However, it is recommended to include the works; i.e. perform Scanning Electron Microscope test (SEM) and X-Ray Diffraction test (XRD) as well as to monitor pH and temperature during curing period for future work.

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