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Evaluation of Vege-Grout Treated Slope by Electrical Resistivity

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ABSTRACT

Soil stabilization using bio-grouting method based on microbial induced calcium carbonate precipitation (MICP) technology has been developed recently to improve or modify the engineering properties of the soil. This new technology could provide an alternative to traditional methods of soil stabilization using soil-cement grouting and chemical grouting. Since there is now a global awareness to alleviate environmental impact for sustainable living, it is important to find alternative resources that are effective and environmental friendly at the same time. Vegetable waste is a good source for the growth of various kinds of microorganisms which is suitable to be applied as bio-grouting material. The bio-grout extract known as vege-grout was able to induce bio-cementation and bio-clogging process between the soil particles when introduced into sandy soil. Electrical resistivity is a useful tool to evaluate a wide range of geotechnical problems especially the subsurface. In this field study, vege-grout from vegetable waste was injected into the soil to strengthen the slope and improve the mechanical properties of the affected area. The changes in the subsurface soil after treatment with vege-grout were evaluated by electrical resistivity measurement. Results showed that the underneath soils have transformed from medium dense sand to dense sand. The water containment in the subsurface appeared to shift deeper into the ground. SEM analysis showed evidence of bio-clogging process as a result of microbial activities in the soil. This analysis showed that the vege-grout from vegetable waste has successfully strengthened and stabilized the slope from soil erosion. This concept can be further explored for future methods in ground improvement.

1. INTRODUCTION

Soil stabilization is commonly practiced in geo-technical engineering where the

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mechanical properties of the soil, specifically for underground and foundation construction, can be enhanced through mechanical and chemical grouting such as compaction and addition of stabilizers and additives. The process of grouting involves the filling of pores or cavities with a liquid form material that will solidify through physical or chemical reaction. The injection of grout can improve the shear strength and decrease permeability by increasing the soil cohesion. However, some of the chemical additives used in the grouting mixture may contaminate the environment (DeJong et al, 2015). Since the global community now is more concerned on the environmental impact of non-renewable resources, new method and technology has been discovered and extensively researched to provide sustainable solutions for greener and cleaner environment.

Recently, many have been written on microbial application in soil reinforcement studies using specific microorganism such as the ureolytic bacteria. This process is known as microbial induced calcium carbonate precipitation (MICP), and this phenomenon normally occurs in environment rich of urea and calcium ions. Although, calcium carbonate precipitation can be achieved by different bio-chemical processes including urea hydrolysis, denitrification and sulphate reduction, the ureolytic pathway is most preferred by many researchers because the production of calcite can be produced more using bacterium with a highly active urease enzyme (Hamdan et al, 2017). This new microbial technology has many potential applications including improvement of engineering properties of soil and reduction in permeability. The precipitated calcium carbonate acts as binding agents between the soil particles through the bio-clogging or bio-cementation process that lead to the reduction in porosity. Not only that, this technology has been applied in concrete remedial, and the latest is the innovation of bio-bricks from bacteria. The mechanisms of bio-chemical pathway of these bacteria through urea hydrolysis enable the precipitation of calcium carbonate or calcite in the soil and simultaneously solidify liquefiable soil (Cheng, L. and Shahin, M., 2016).

Previous works by a group of researchers from UNITEN have discovered the beneficial use of vegetable waste in soil reinforcement. In this study, the micro-organisms were obtained from the fermentation of vegetable waste mixtures. During fermentation, a high number of spoilage organisms that cause rot in vegetables are produced since these organisms come from the environment such as the soil and water. (Medina-Pradas et al, 2017). These microorganisms from the vegetable waste substrate can help aggregate formation in soil particles through several bio-chemical pathways (Rashid et al, 2016). In previous work, laboratory analysis on the engineering properties of liquefied soil treated with vege-grout showed an increase in compressive strength and reduction in permeability. It was discovered that the indigenous microorganisms in the vege-grout were responsible for the activitie (Omar et al, 2016). Based on these results, the application of vege-grout was further explored on the field where vege-grout was introduced into the ground through injection.

The effect of vege-grout application in the field study will be monitored using electrical resistivity it is cost-effective and the most common technique to investigate the subsurface profile. Hence, the objective of this study was to analyze the application of vege-grout in a field experiment by electrical resistivity to evaluate the vege-grouting effect in the subsurface soil.

2. SITE AND GEOLOGY OF STUDY AREA

The study area was a cut slope located along a North South Expressway as shown in Figure 1. The geological description of the area composed mainly of granitic rock from igneous activity. Granite is one type of igneous rock composed of a variety of minerals such as quartz, feldspar and mica. Granite is hard, tough and resistant to fracture because of the interlocking structure of the minerals within it but due to weathering and set of discontinuity occur at the particular area, the strength of granite is reduced. This site is underlain by intrusive rocks, mainly Biotite Granite which consists of fine, medium and coarse-grained granites. Most of the granite that was exposed here has undergone weathering process. Due to this weathering process, the exposed rock is made up of weathered granite Grade IV to VI. This granite intrusion was then covered by the quaternary sediment that can be seen around the hill. Based on the geophysics survey, the site area consists of clayey sand and weathered granite. The main type of soil in this area consists of sandy soil from weathered granite Grade IV to V.

Fig.1 Study site for field experiment

2.1 Preparation of vege-grout

In this study, the micro-organisms were obtained from the fermentation of vegetable waste mixtures. First, approximately 100.00 kg of vegetable of different types were collected from the surrounding markets, and brought to the laboratory to be processed. All vegetables were thoroughly cleaned with distilled water to avoid cross

contamination. Then the vegetables were cut into smaller pieces to increase the surface area of the vegetables. More amounts of vegetables can produce more micro-organisms. The vegetables were then kept tight in clean containers under room temperature for a month. During fermentation, a high number of microorganisms which contribute to the spoilage will be produced (Maspolim et al, 2015). After a month, the vegetable waste liquid was filtered and transferred to another container. The final liquid was brown in color that showed sedimentation of live microorganisms. The process of vege-grout preparation is illustrated in Figure 2.

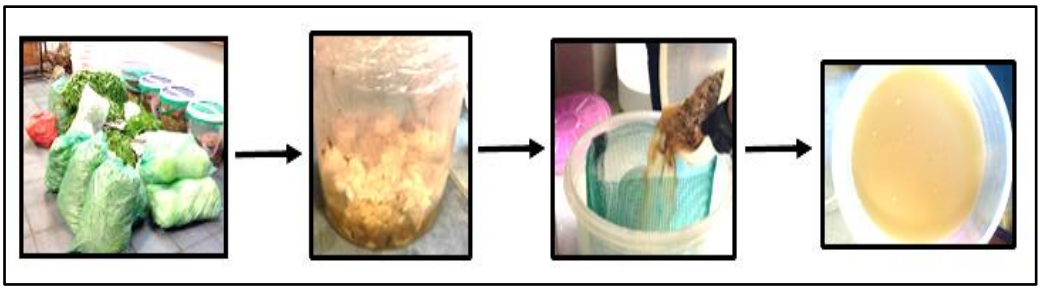

Fig. 2 Preparation of vege-grout from vegetable waste

2.2 Field experiment

Precast PVC pipes were installed at designated drilling holes for grouting injection purposes. Holes were drilled using portable drilling soil. Drilling locations were at least 1 meter between each hole. The size of drilling hose was 40mm in diameter. The depth of drilling was 0.50 m and 1 m from surface in vertical direction (90 degree). The vege-grout liquid will be injected through the PVC pipes (Figure 3).

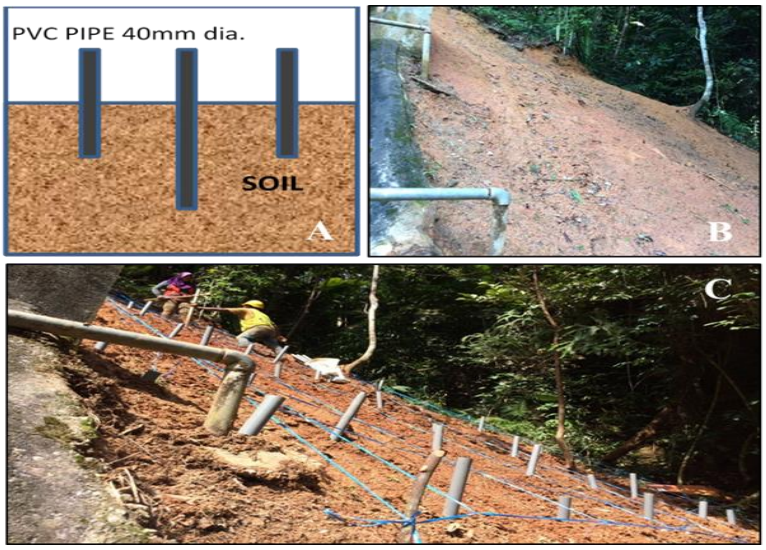

Fig. 3 Installation of PVC pipes for grouting

2.2 Electrical resistivity study

ABEM Terrameter LUND Imaging System was used to determine the characterization of the soil. The testing procedure was carried out according to ABEM INSTRUCTION MANUAL TERRAMETER SAS 1000/4000. ABEM SAS 4000

Terrameter (Sweden) was used to measure the potential between the electrodes whereby the current source was provided by ES 10-64 basic system 4 channels. First the terrameter was set up as shown in Figure 4. A total of 41 electrodes were inserted into the ground at an equivalent distance with DC current source connected to the electrodes. The spacing between the electrodes depends on the total length of resistivity line. The line where electrodes are arranged is known as resistivity line. (Figure 4).Electrode cables will be placed parallel to the resistivity line and connected to the electrode by using cable-to electrode jumper. The data captured by electrical imaging was converted using RED2DINV software, version 4.02.02. For this study, Wenner-Schlumberger array arrangement was used to conduct the resistivity study because it is more sensitive to both horizontal and vertical variations (Loke et al, 2015).

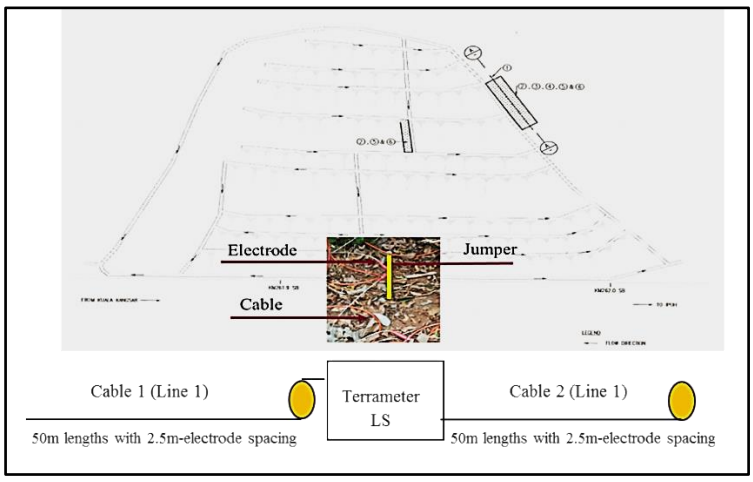

Fig. 4 Arrangement of electrode arrays

3.0 RESULTS AND DISCUSSION

The resistivity images recorded is in the form of 2 dimensional axes, where y-axis is the depth below ground level and x-axis is the length of survey line where the electrodes were buried. This survey was able to detect the type of soil and rock layers to a depth of 17 meters from ground level. Figure 5 showed the resistivity profile of study area. Generally, the subsurface is made up of sandy soil (resistivity value of between 30 to 250 ohm meter). The hard layer from the weathered rock has been indicating by resistance value more than 250-ohm meter. Each individual line can achieve an accuracy of + 10% whilst at the intersection a better accuracy of +5% can be achieved. Based on the resistivity survey, the length of survey line is 100 meter. A unit electrode spacing of 2.5 meter was used which give a maximum depth of investigation of about 17 meter. The loose to dense layers of clayey sand were interpreted with range of resistivity value 50-ohm meter to 350-ohm meter, which refers to current soil condition at failure area. Hard layer was discovered at 8.67 meter at the middle below the ground surface, which has resistivity value of more than 400-ohm

meter. The hard layer is a weathered granite grade V having major jointing and fracturing consist of very dense soil. Ground water table was interpreted as 1-100 ohm meters (dark blue) which is water was saturated with soil at upper hard layer (>400 ohm meter). Infiltration rate for loose soil is much higher than dense soil due to pore size between soil particles (Figure 6).

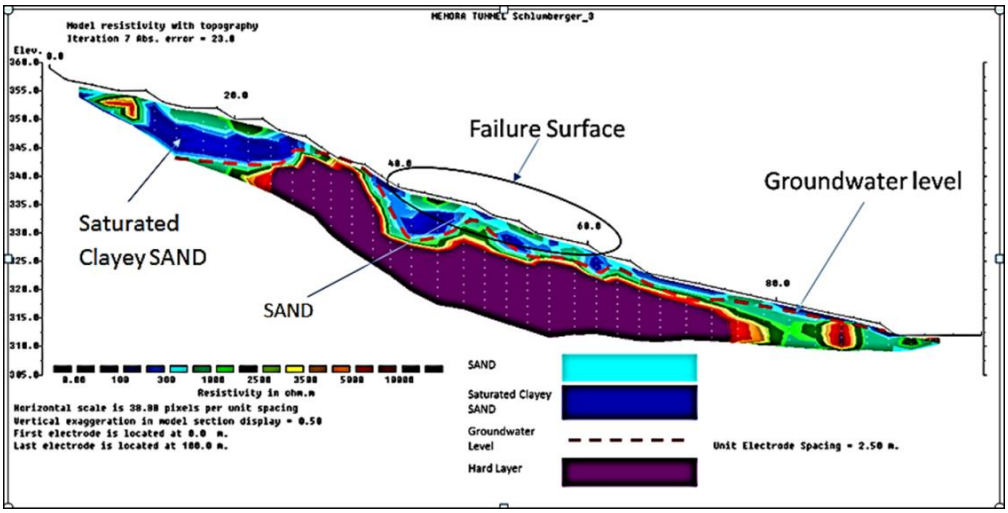

Fig. 5 2D resistivity model of study area

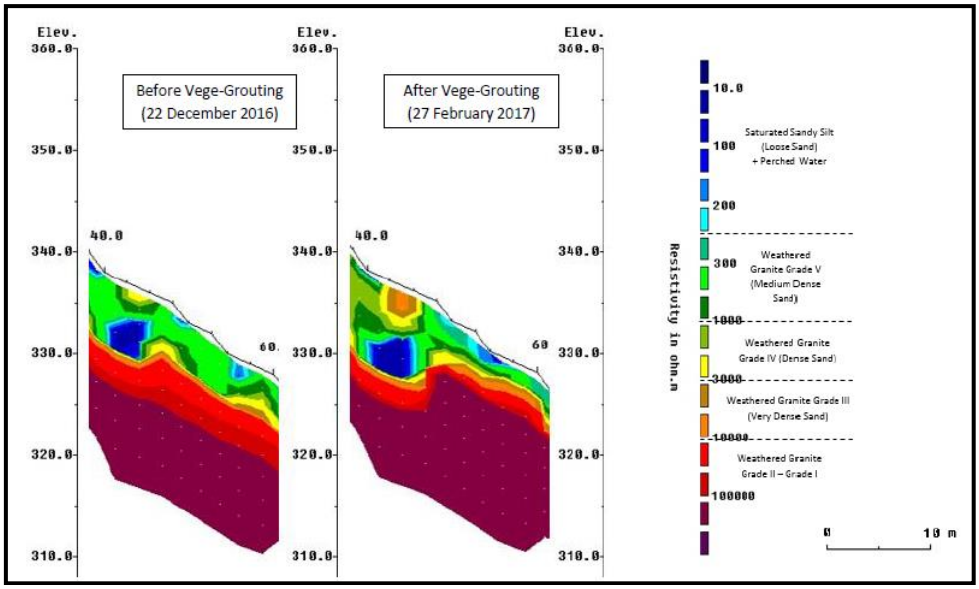

Fig. 6 Comparison of soil profile before and after vege-grouting

Fig.7. Observation of study area before (A) and after vege-grout treatment (B)

After the treatment of vege-grouting, it was observed that the surface of the study area which was previously exposed to erosion was covered with green grass (Figure 7).

3. CONCLUSIONS

The application of vege-grout from vegetable waste in soil stabilization was intended to improve the physical properties of soil and reduce the liquefaction. This study demonstrated that vege-grout from vegetable waste can be used as stabilizing agent for soil and was effective in stabilizing the soil. This method is environmental friendly and economical. Furthermore, the vege-grout liquid can reach the small spaces within the soil particles and induce bio-clogging. The method was cost-effective since it can save up to 25% compared to normal grouting. This application can be used to replace current conventional grouting, and it is suitable to treat large scale area.

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