International Journal of Engineering & Technology, 7 (4.35) (2018) 168-171

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Evaluation of Vege-Grout Treated Slope by Electrical Resistivity

INZ Baharuddin[1]*, Hairin Taha[2], RC Omar[3], R. Roslan[4], FS Buslima[5], K Rizal[6]

[1,2,3, 4,5]Institute of Energy Infrastructure
University Tenaga Nasional, 43000 Kajang, Selangor, Malaysia
[6]PLUS Malaysia Berhad, 47301, Petaling Jaya,Selangor, Malaysia
**Corresponding Author E mail: Intan@uniten.edu.my*

Abstract

Soil stabilization using bio-grouting method based on microbial induced calcium carbonate precipitation (MICP) technology has been developed recently to improve the engineering properties of the soil. This new technology could provide an alternative to traditional methods of soil stabilization using soil-cement and chemical grouting. 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. In this 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. Resistivity test showed the resistance in the soil has increased after the grouting using vege-grout. Results indicated 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.

Keywords: *Soil stabilization;vege-grout; slope; erosion; electrical resistivity*

1. Introduction

Soil stabilization is commonly practiced in geo-technical engineering where the mechanical properties of the soil, specifically for underground and foundation construction, can be improved through mechanical and chemical grouting such as compaction and addition of stabilizers and additives [1]. Grouting is one of the ground improvement methods to improve the strength of soil. The process of grouting involves the filling of pores or cavities with a liquid form material that will solidify through physical or chemical reaction [2]. 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 and surroundings. Mechanical stabilization methods can be costly and laborious. The use of cement in grouting mixtures generates high energy consumption and carbon dioxide (CO_2) emission [3]. Since the global community now is more concerned about the environmental impact of non-renewable resources, new method and technology has been proposed and extensively researched to provide sustainable solutions for greener and cleaner environment, including the possible use of industrial waste [4-6].

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 [7]. 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 [8-9]. 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 [10-12]. 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. One comparison study showed that the bio-treated soil using MICP was more energy saving, cost effective and environmental friendly compared to that of cement grouting [13].

Previous works by a group of researchers from UNITEN have discovered the beneficial use of vegetable waste or vege-grout in soil reinforcement [14-15]. Instead of using cultivated bacteria, synthetic urea and calcium chloride ($CaCL_2$), vege-grout can be used as an alternative substrate to induce calcite precipitation. 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 [16]. These microorganisms from the vegetable waste substrate can help aggregate formation in soil particles through several bio-chemical pathways [17]. 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 microorganism in the vege-grout were responsible for the activities which has been demonstrated in a similar study [18].

Based on these promising results, the application of vege-grout was further experimented on the field where vege-grout was used as grouting bio-material for soil improvement.
The effect of vege-grout application in the field study will be monitored using electrical resistivity since 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. Geophysics survey of the site area indicated that the soil was made up of Clayey SAND and weathered granite. Sandy soil was the main type of soil in this area

Fig. 1: Study area 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 microorganisms. The vegetables were then kept tight in clean containers under room temperature for a month. During fermentation, a high number of spoilage will be produced. 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.

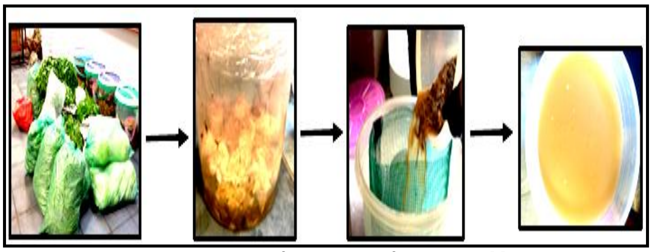
Fig. 2: Preparation of vege-grout from vegetable waste

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 into the ground through the PVC pipes (see Figure 3).

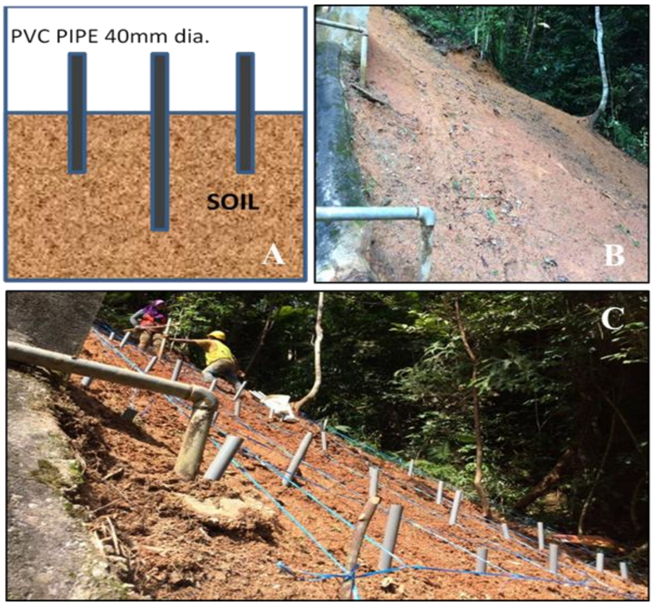

Fig. 3: Installation of PVC pipes for grouting

2.3. Electrical Resistivity Study

Electrical resistivity of the underneath ground was measured through the differences in resistivity values between different subsurface materials. The distance between the electrodes, the used array, the volume of current introduced in the ground and the sensitivity of the measuring equipment can directly influence the measured potential. Schlumberger Array was used in this study area using the arrangement carried out with a multi-electrode resistivity meter system (ABEM Terrameter LS) as shown in Figure 4. The data captured by electrical imaging is a raw data that will be transferred to the software program called RED2DINV software.
In general, the resistivity method measures the resistivity distribution of the subsurface materials such as the soil profile, depth of the subsurface materials, contour and groundwater level. This method has the advantage of providing the resistivity index of the ground as well as the subsurface resistivity image. Surface resistivity imaging has been one of the most effective methods that provide a detailed picture of the underground conditions without digging and deprived of other geophysical tools. In many cases, resistivity imaging survey can be planned, executed, and the data can be interpreted in a matter of hours while causing minimal or no impact to the environment.

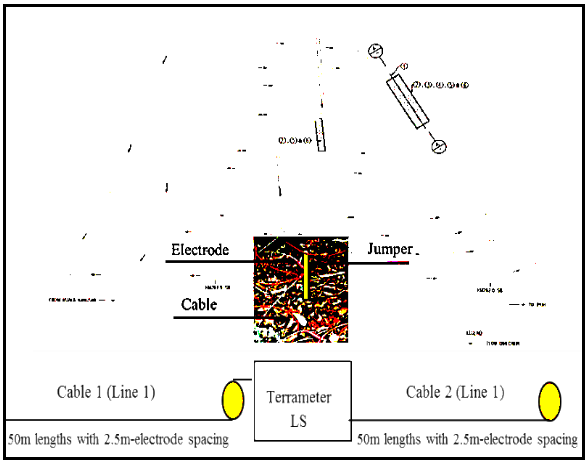

Fig. 4: Arrangement of electrode arrays

3. Results and Discussion

Figure 5 shows the resistivity images in the form of 2 dimensional axes, the depth below ground level is represented by y-axis and the length of survey line where the electrodes were buried was represented by x-axis. This survey was able to detect the type of soil and rock layers to a depth of 17 meters from ground level with 100.0 meters length. The resistivity result showed the loose to medium dense layers of sandy silt were interpreted with range of resistivity values of 50 Ohm-metre to 500 Ohm-metre.
The observation and resistivity results of the study area treated with vege-grout are shown in Figure 6. The saturated layer showed zones of low resistivity with groundwater in the subsurface. After the vege-grout treatment, the resisitivity values were higher due to the hardened composition of the soil. Hard layer was detected with range of resistivity value more than 250 ohm.metre. The hard layer consists of weathered granite grade V to II. From the results of the resistivity value, the value showed an increase from 300 ohm.m to 5000 ohm.m indicating that the soil has been transformed into medium dense to dense sand. After approximately two months, the surface area has been covered with new vegetation such as grass and small plants that helped to reduce erosion (See Figure 7). Studies have shown that grass and shrubs are very effective in reducing run-off and erosion effects [19]. Scanning electron microscope (SEM) observation of the treated soil showed evidence of bio-clogging between the soil particles due to the microbial activities in the soil and vege-grout (Figure 8).

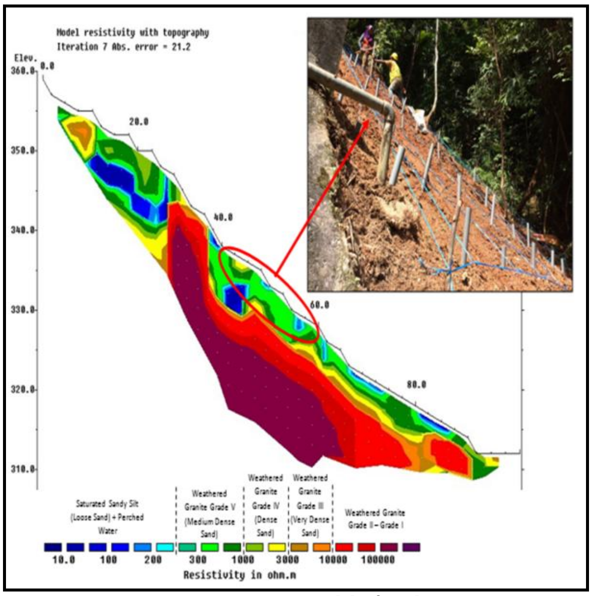

Fig. 5: 2D resistivity model of study area

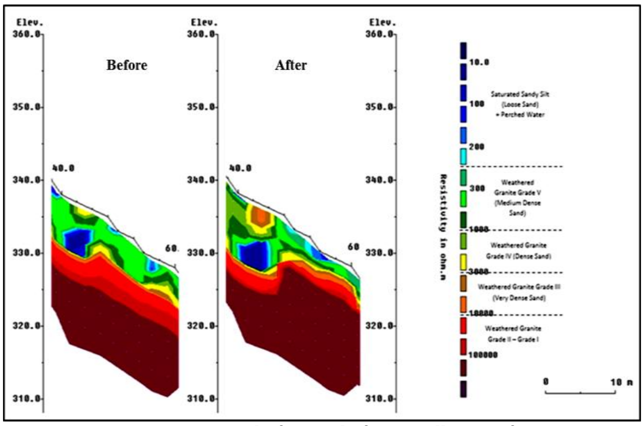

Fig. 6: Resistivity survey before and after installation of vege-grout

Fig. 7: A) Study area showed eroded surface B) After vege-grout treatment, study area showed growth of grass covering the top-soil

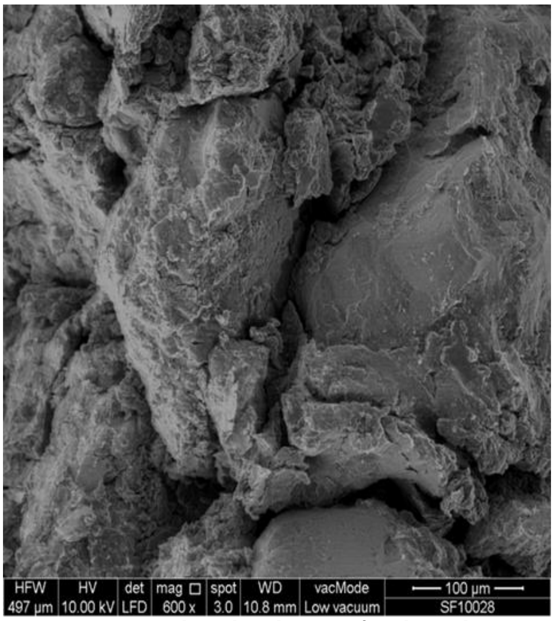

Fig 8: SEM shows bio-clogging of sand particles

4. Conclusion

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. It is proven to provide unique solution in geotechnical engineering problems which its ability to self-sustain is seen as an advantage to the stakeholders. It is seen that the system could be a solution to remote area where ingress/egress to the problematic area is limited. The application of vege-grout could be tested for various engineering problems including water seepage, slope stability and settlement and is deemed to be all-rounded system. This method is environmental friendly and economical. It is can reduce operational cost up to 25% compared the conventional grouting.

Acknowledgement

This research was funded by Ministry of Higher Education through Innovation & Research Management Centre (iRMC), UNITEN with research grant no. 20160202PRGS

References

[1] Kalantary F and Kahani M (2018) "Optimization of the biological soil improvement procedure," International Journal of Environmental Science and Technology, pp. 1-10.

[2] Huang Y and Wang L (2016) "Experimental studies on nanomaterials for soil improvement: a review," Environmental Earth Sciences, vol.75, pp. 497.

[3] Pineda P, García-Martínez A and Castizo-Morales D (2017) "Environmental and structural analysis of cement-based vs. natural material-based grouting mortars Results from the assessment of strengthening works," Construction and Building Materials, vol. 138, pp. 528-547.

[4] Pourakbar S, Asadi A, Hua, BB and Fasihnikoutalab MH (2015). "Stabilization of clayey soil using ultrafine palm oil fuel ash (POFA) and cement," Transportation Geotechnics, vol.3, pp. 24-35.

[5] Roy A (2014) "Soil stabilization using rice husk ash and cement," International Journal of Civil Engineering Research, pp. 49-54.

[6] Al-Amoudi OSB, Al-Homidy AA, Maslehuddin M and Saleh TA (2017) "Method and Mechanisms of Soil Stabilization Using Electric Arc Furnace Dust," Scientific Reports, vol.7, pp 466-476.

[7] Mujah D, Shahin MA and Cheng L (2017) "State-of-the-art review of biocementation by microbially induced calcite precipitation (MICP) for soil stabilization," Geomicrobiology Journal, vol. 34, pp. 524-537.

[8] N Kavazanjian, Jr E, Rittmann BE and Karatas I (2017) "Carbonate mineral precipitation for soil improvement through microbial denitrification," Geomicrobiology journal, vol. 34, pp. 139-146.

[9] Zhao Q, Li L, Li C, Li M, Amini F and Zhang H (2014) "Factors affecting improvement of engineering properties of MICP-treated soil catalyzed by bacteria and urease," Journal of Materials in Civil Engineering, vol. 26.

[10] Achal V and Kawasaki S (2016) "Biogrout: a novel binding material for soil improvement and concrete repair," Frontiers in microbiology, vol. 7, pp. 314.

[11] Bernardi D, DeJong JT Montoya, BM and Martinez, BC (2014) "Bio-bricks: Biologically cemented sandstone bricks," Construction and Building Materials, vol.55, pp. 462-469.

[12] Bu C, Wen K, Liu S, Ogbonnaya U and Li L (2018). "Development of bio-cemented constructional materials through microbial induced calcite precipitation," Materials and Structures, vol. 51, pp. 30.

[13] Naeimi M and Haddad A (2018) "Investigation on the Environmental Impact of Soil Improvement Techniques: Comparison of Cement Grouting and Biocement," In GeoShanghai International Conference, pp. 483-490.

[14] Omar RC, Roslan R, Baharuddin INZ and Hanafiah MIM (2016), "Micaceous Soil Strength and Permeability Improvement Induced by Microbacteria from Vegetable Waste," In IOP Conference Series: Materials Science and Engineering 160.

[15] Omar RC, Hairin Taha, RR & Baharudin INZ (2018) "Study of Bio-Grout Treated Slope Models Under Simulated Rainfall," International Journal Of Geomate, vol.14, pp. 154-159

[16] Medina-Pradas E, Pérez-Díaz IM, Garrido-Fernández A and Arroyo-López FN (2017) "Review of Vegetable Fermentations With Particular Emphasis on Processing Modifications, Microbial Ecology, and Spoilage," The Microbiological Quality of Food , pp. 211-236.

[17] Rashid MI, Mujawar LH, Shahzad T, Almeelbi T, Ismail IM & Oves M (2016) "Bacteria and fungi can contribute to nutrients bioavailability and aggregate formation in degraded soils," Microbiological research, vol. 183, pp. 26-41.

[18] Smith AJ, Pritchard M and Bashir S (2017) "The Reduction of the Permeability of a Lateritic Soil through the Application of Microbially Induced Calcite Precipitation," Natural Resources.

[19] Richet JB, Ouvry JF and Saunier M (2017) "The role of vegetative barriers such as fascines and dense shrub hedges in catchment management to reduce runoff and erosion effects: Experimental evidence of efficiency, and conditions of use," Ecological Engineering vol.103, pp. 455-469.