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Slope Improvement using Combination of Coconut Husks, Coconut Flakes, Luffa, Pineapple Leaves and Vege-Grout

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Abstract:

The principle of sustainability is about maintaining and improving environmental, social and economic resources to meet the needs of current and future generations. The application of geotextile and micro-bacteria from agricultural waste as Vege-Grout-COLUFNAS, as geotextile and soil induced is therefore implemented as an option for soil treatment/slope improvement. Application of Vege-Grout-COLUFNAS at the experimental site has shown that natural geotextiles have an important impact on managing ground erosion based on the site observation and measurement shows the reducing of the weight of soil reduced by 70 %. These researches have shown that the mixed implementation of Vege-Grout-COLUFNAS indicates an increase in safety factor (FOS) from 1,192 to 1,958. It demonstrates that the Vege-Gout-COLUFNAS type J seam was used as tensile reinforcement to stabilize the slope and also acts as a filter that prevents internal erosion within the slope.

Keywords: geotextile, pineapple leaves, luffa, soil erosion, bio-grout

I. INTRODUCTION

In Malaysia, slope instability regarding new development is a continuing issue as slope defects endangered public safety and continue to result in expensive repair work. The slope failures characterization is complex because it is difficult to discern and measure factors affecting slope stability, especially parameters of soil shear strength. Reducing the slope failures requires alternatives to stabilize the causes of slope instability. Using pile components, slope improvement of soil physical characteristics and reinforcement can be an efficient remediation technique to prevent slope movement in weak soils where improved drainage does not provide sufficient stability. However, the need for green technology to improve slopes will be introduced

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in the process of adapting sustainable concept to Malaysia's infrastructure design and remedial work. The introduction of green technology to the construction practiced requires a win-win situation on the part of society and the client. European researchers show that society has benefited directly from developments in studies in which biological procedures have been instrumental in providing viable alternatives to long-standing engineering challenges. At the surface, soil stabilization can be achieved by using common constructive approaches like compaction, adding nails or sheets in a slope or mixing soil with lime or cement [1]. Lately, ecological approaches to prevent soil erosion are getting more attention, like planting trees, grasses, and shrubs or stimulate mussel beds [2] and [3]. When stabilization of a soil mass is required at depth, these superficial techniques are insufficient and strengthening techniques, like deep mixing, cement or chemical grouting are being used [4].

However, as the zone of influence of these methods is limited to the proximity of the mixing equipment or due to the high viscosity or short hardening time of the injected grouts, these traditional methods are not suitable for treating large volumes. Chemical or cement grouting techniques are often costly and environmentally unfriendly and require heavy machinery, disturbing urban infrastructure. Finally, these methods significantly reduce the permeability of the strengthened soil, which hinders groundwater flow and limits the injection distance, making large-scale treatment unfeasible. Currently, the potential of biological techniques for ground reinforcement which is vege-grout is being investigated [5], [6] and [7].

Micro-organisms can catalyze chemical reactions in the subsurface when supplied with suitable substrates resulting in precipitation (or dissolution) of inorganic minerals, which changes the mechanical properties of the soil. This study focuses on microbial induced calcium carbonate precipitation (MICP) by urea hydrolysis and its potential as a ground reinforcement method.

New solutions through a combination of luffa, vegetable waste, coconut flakes as geotextile and vege-grout have provided more efficient, environmentally friendly, and/or economic solutions relative to traditional treatments that utilize man-made materials. In this research study, the application of microbiological process will be used to improve the physical properties of soils and the landscape of the particular problematic slope.

II. DEVELOPMENT AND EXPERIMENTAL

A) Development of Innovative Technology

The development of innovative technology for the in-situ strengthening of soil/soft rock using bacteria, Calcite (Calcium Carbonate) precipitation fragmented from vegetable waste with the combination of geotextiles from agricultural waste are used for slope improvement. This technology creates a solution for geotechnical problems especially for protection from land degradation offers a reliable and economical alternative to minimize and control the effect of erosion and landslide to support global initiative in sustainable development. This technology promotes the ability of soil to self-sustain named as vege-grout-colufnas, the combination name for geotextile and grout from vegetable waste.

In a wide context, soil improvement includes the different techniques used to modify the characteristics of a soil to enhance the efficiency of its engineering. For a multitude of engineering works, soil stabilization is used to improve soil strength or stability. Several techniques of soil therapy implemented to tackle soil parameter deficiencies. However, many of these techniques need to be improved. There are several drawbacks to these present standard techniques that need improvement. The main disadvantage is the issue of sustainability. The principle of sustainability is about maintaining and enhancing environmental, social and economic resources to satisfy present and future generations ' requirements. Therefore, the application of geotextile and micro-bacteria from agriculture waste as vege-grout-colufnas, as geotextile is introduced as an alternative in soil treatment/ slope improvement. The use of vege-grout-colufnas, in this research helps:

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i. To identify the soil strength of the soil before and after treatment using vege-grout-colufnas.

ii. To analyze the erosion rate and the stability of the treated slope.

B) Vege-Grout Production, Geotextile Materials and Design

Geotextiles are produced from a mixture of agricultural waste such as coconut husks, coconut flakes, luffa and pineapple leaves, known as COLUFNAS. Coconut husks, coconut flakes, luffa, and pineapple leaves are rich in cellulose and biodegradable. Coconut husks are used as buffers to trap soil losses during erosion and landslides. Whereas coconut flakes are used as fertilizer for grass growth in erosion-prone areas [8]. Luffa acutangula has an outstanding capability to remove and decrease heavy metals in water. Luffa is commonly used as a biodegradable hybrid composite worldwide, remarkably permeable and low-cost, high tensile and flexural strength [9]. By offering an open grid-like configuration to help increase the power of pineapple leaves and coconut rusk, Luffa was used to reinforce the geotextile structure. Pineapple leaves are chosen based on their mechanical features, which are the highest tensile strength and tensile module and show that they can be used to design engineering material for construction [10-11]. With coconut husk and luffa, the geotextile layers of dried pineapple leaves were compelled. Sandwiches between them are coconut flakes.

COLUFNAS have been sewn using jute yarn with a diameter of 1.2 mm. Jute yarn is selected as a thread due to the slightly polyester-like properties that may produce seaming higher strength geotextiles with a cross-machine directional strength.

The mixture of these three material influences on the strength and the condition of the material looks like woven material. That is why the J-seam layout of the geotextile is used. Three kinds of seam are frequently used: (1) ' flat ' or ' prayer ' seam, (2) ' j ' seam, and (3) ' butterfly ' seam. Fig. 1 shows the three kinds of seam. The "prayer" seam is the easiest to make and is commonly used for the recommended seam strength of 42 kN /m or less. The "J" and "butterfly" seams are more hard to produce and are frequently used to create greater seam strengths.

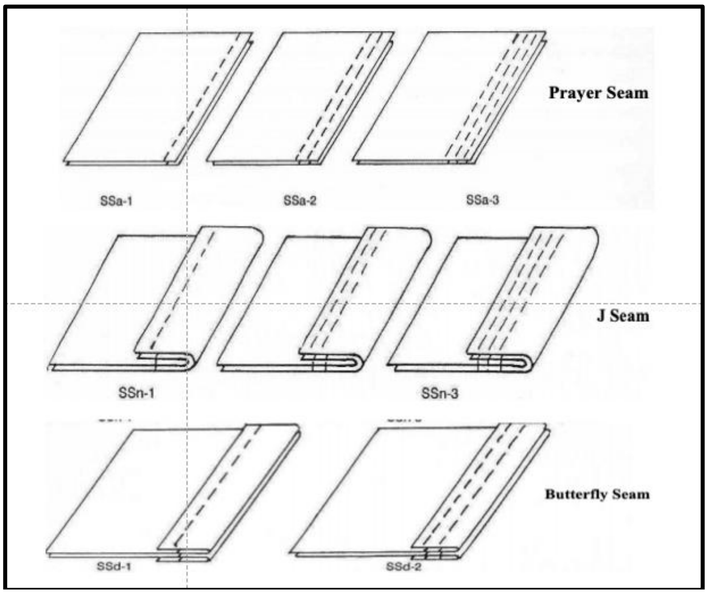

Fig. 1 Three type of seam

The "J" seam is a high-strength seam that is ideally suited for medium woven geotextiles such as these COLUFNAS. The "J" seam offers the greatest seam strength of the geotextile seed [12]. The type 401 double thread 'lock stitch' is selected for sewing because it prevents unravel and greater strength, which is more than 26 kN / m compared to the type 101 single thread stitch, which is simple to unravel and low in intensity. Geotextile is stitched using a stitch density of 3 to 6 per 2.5 cm to produce greater seam efficiency. Fig. 2 illustrates the geotextile COLUFNAS.

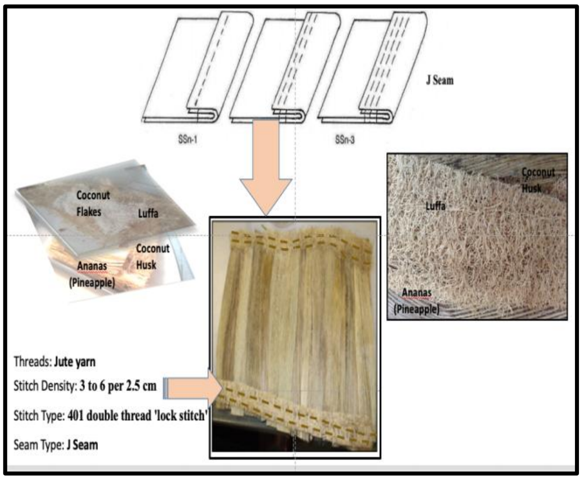

Fig. 2COLUFNAS Geotextile

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Vege-grout was produced for slope improvement through the fermentation of mixed vegetable waste consisting of spinach, cucumber, water spinach, long bean and cod [13]. In order to produce the vege-grout fluid, the extract was filtered after that. The vege-grout contained vital components, such as silica, iron, and calcium, required for the bio-cementation method. These components are crucial to the development of biotechnology processes in the production of biomaterials [14].

C) Experimental Site

The soil sample was assembled at the slope near to College of Engineering, Universiti Tenaga Nasional (UNITEN) adjacent to the drainage system where a slope failure occurred (Fig. 3). The slope surface was eroded due to the influence of rainfall. The sample was collected at an altitude of 70 m in the middle of the slope. The sample was collected using a 38 mm and 60 mm diameter cylindrical tube with a depth below 1.5 m. The soil was classified with intermediate plasticity as sandy SILT. The content of liquid soil was 38.38 percent (between 30% and 50%). Soil liquidity index (LI) where the relative consistency in the natural state of the cohesion soil was -0.31, which is less than 1. The soil was well-graded and has more than 50 percent (63.74 percent) of fine-grained particles.

Fig. 3 Experimental site

D) Vege-grout and geotextile-COLUFNAS Application

COLUFNAS was designed as a surface geotextile to avoid soil erosion and shallow landslides. The test plot was arranged at the site following the grid approach to the testing and assessment of COLUFNAS for the improvement of slopes. Grid A was used as a control grid without any vege-grout or COLUFNAS (negative control). In Grid B, the soil was treated with vege-grout. Grid C, in the other hand, used both vege-grout and COLUFNAS. Grid B and Grid C will be monitored and assessed based on physical observations, site, and laboratory tests. The monitoring was performed every seven days for a total of 35 days. Fig. 4 showed grids A, B and C on the first day of implementation of COLUFNAS and Vege-grout.

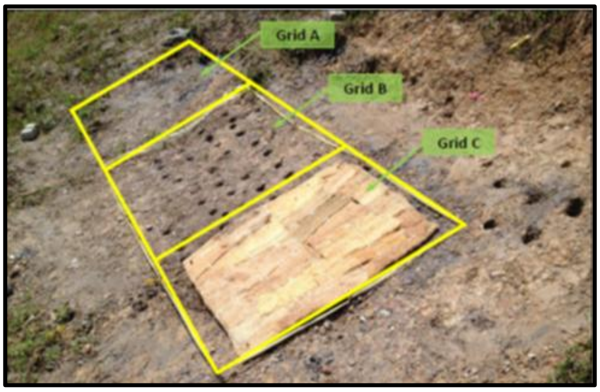

Fig. 4 Geotextile and bio-grout application on day 1

PVC (polyvinyl chloride) tube with a diameter of 25 mm was trimmed to 1 m in length as shows in Fig. 5. Small holes were drilled on tubes with a diameter of 5 mm at a range of 150 mm to allow the bio-grout to flow horizontally along the pipe during the grinding phase. In a group of 11 pipes for each grid, the pipes were driven into the ground by about 500 mm to 700 mm. The vege-grout was then gravitationally poured into the pipe. The grubbing speed was approximately 1.8 mL / s per liter or 30 minutes. The grubbing technique used a total of 45 liters of vege-grout.

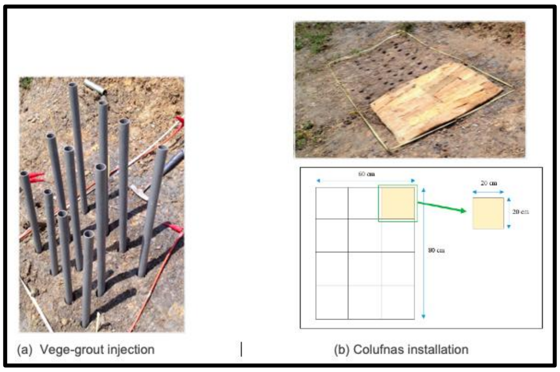

Fig. 5installation and vege-grout injection with COLUFNAS

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III. THE OBSERVATION, TESTING AND DISCUSSION

The observation showed after 28 days that in the B and C grids a fresh set of grass had grown which had been injected with vege-grout compared to Grid A (Fig. 6). The COLUFNAS in Grid C underwent a natural degradation process throughout the experimental period, but there were no significant signs of further erosion in the soil below the geotextile layer. Under the COLUFNAS there was a large quantity of trapped soil and tiny gravel as shown in Fig. 7. The soil particles are held in location by COLUFNAS while the vegetation is formed. Within COLUFNAS, coconut flakes generate valuable humus to fertilize the grass for growth. The COLUFNAS using J seam did not degrade quickly, giving enough time to re-stabilize the soil surface. Furthermore, degraded natural geotextile promotes fresh vegetation and by microbial activity adds nutrients to soil [15]. On the other side, the COLUFNAS using J seam is used to regulate the soil when preventing particles suspended in the fluid flow of the surface while allowing the fluid to move through (Fig. 7). The particles accumulate against the COLUFNAS after a certain moment, reducing the fluid flow and increasing the stress against the COLUFNAS.

Fig. 6 Observation at Day 28 for Grid A, B and C

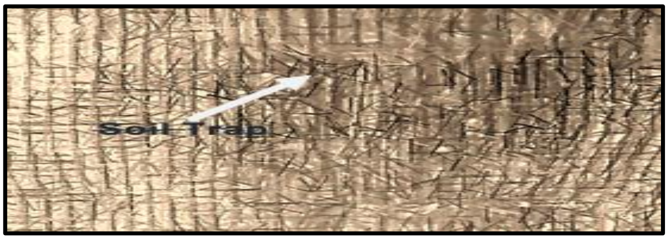

Fig. 7 Tiny grass, trapped soil and tiny gravel beneath the COLUFNAS

The slope surface of the A and B grids was mildly eroded on the 21st day following the vege-grout treatment. Observation after 35 days shows the Grid B was completely covered by grass compared to Grid A. In Grid C, as shown in Fig. 8, the geotextile was degraded by 95% and the surface was partly coated by grass.

Fig.8 Observation of Grid A, B and C on day 35

Observations in Fig. 9 have shown that the treated soil has considerably improved and soil erosion has been monitored and avoided. The COLUFNAS using J seam has produced a important contribution to the soil surface's safety and long-term stability. It is not prone to rapid degradation and is more durable, allowing vegetation to grow in a shorter moment. Due to the increased supply of nutrients, bio cementation process, soil fertility, and properties have been enhanced.

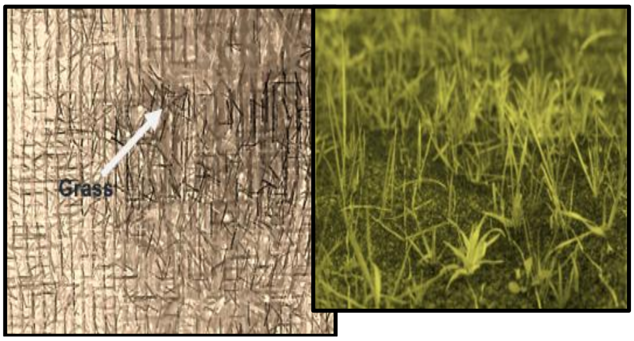

Fig.9 COLUFNAS hold the soil particles in place, while the vegetation becomes established

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An eroded soil sample from Grid C is measured and the outcome is shown as Table 1. It shows that COLUFNAS keeps soil particles in location, traps precious humus from coconut flakes and vege-grout to fertilize grass for growth. Table 1 demonstrates the weight of soil erosion reduced by 70% because, during the curing period, the cementation process occurs owing to the method of bio-mineralization through microbial activity [15].

TABLE I
SOIL LOSS BEFORE AND AFTER USING COLUFNAS

No	**Eroded Soil (g), before COLUFNAS installation**	**Eroded Soil (g), after COLUFNAS installation**
7 days	2.25	0.15
14 days	2.25	0.11
18 days	2.25	0.05
35 days	2.25	0.02

Grid C soil sample treated with vege-grout and COLUFNAS demonstrates incremental cohesion (c'(kPa))and angle of friction(ϕ'(°)) towards the curing moment. Incremental cohesion (c'(kPa)) and angle of friction (ϕ'(°))will improve soil consistency and density, improving the shear strength of the soil. The soil values of cohesion (c'(kPa)) and angle of friction(ϕ'(°))were risen by 117.77 percent and 31.53 percent after 35 days of healing relative to the initial soil of Grid C as shown in Table 1. Whereas for 21 days the curing rate is 65.54 percent and 30.56 percent for cohesion (c'(kPa)) and angle of friction(ϕ'(°)).

TABLE II
SHEAR IMPROVEMENT FOR TREATED SAMPLE

Curing Time	Cohesion, *c'* (kPa)	Friction Angle, ϕ'(°)	Percentage of Improvement in Cohesion (%)	Percentage of Improvement in Friction Angle (%)
Control	15.93	13.32	N/A	N/A
7 days	25.41	13.40	59.51	0.60
14 days	25.11	15.53	57.63	16.59
21 days	26.37	17.39	65.54	30.56
28 days	32.70	17.44	105.27	30.93
35 days	34.69	17.52	117.77	31.53

Stability analysis of the slope based on curing times 35 days of Grid C is simulate using Slope-W software as shown in Fig. 10. The value of 7 days and 35 days are used, which are cohesion (c') 25.41(kPa) and 34.69(kPa) and angle of friction **(°)**13.40**(°)** and 17.52**(°)**are used. The result shows the increment of the factor of safety (FOS) from 1.192 to 1.958.

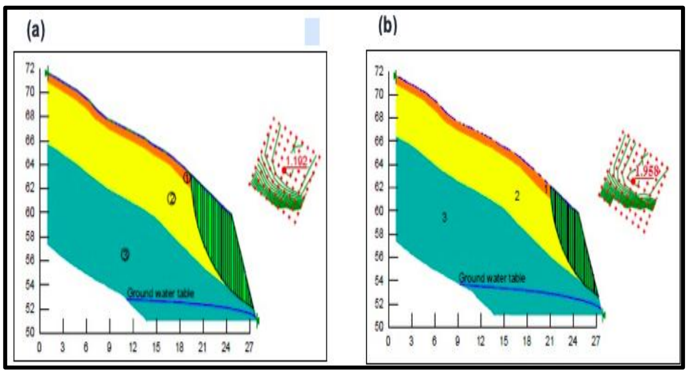

Fig.10(a) Before install COLUFNAS and (b) After install COLUFNAS. The result shows

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VEGE-GROUT-COLUFNAS increase the soil strength and reduced the erosion which induced shallow landslide. Slope stability increase after COLUFNAS installation from F.O.S 1.192 to F.O.S 1.958

IV. CONCLUSION

The use as a green stabilization of the mixture of pineapple leaves, luffa, coconut husks, coconut flakes, and vege-grout has considerably led to the safety and long-term stability of the soil surface. It is not prone to rapid degradation and is more durable, allowing vegetation to grow in a shorter moment. Also, the soil properties have been improved and it shows an increase in soil strength after treatment and decreases the erosion rate and increases the stability of the slope.

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