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GEOTEXTILE FROM PINEAPPLE LEAVES AND BIO-GROUT FOR SLOPE STABILIZATION AND EROSION CONTROL

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ABSTRACT: Geotextiles are widely used in the civil engineering projects as ideal materials for building, road and railway constructions for separation, reinforcement, filtration, drainage, ground and pavement stabilization and soil erosion control. Geotextile made of synthetic polymeric products dominates the current market more compared to natural geotextiles due to many advantages such as the function, performance and variable applications. However, synthetic geotextiles are non-biodegradable and expensive, and may have an impact on the environment. On the contrary, natural geotextiles from plant fibers offers sustainable alternative that is safe and economical. The purpose of this study was to investigate the effectiveness of natural fibers from pineapple leaves and luffa as geotextile materials in combination with bio-grout from vegetable waste with respect to erosion control. Application of these two methods at the experimental site showed that the natural geotextile has significant influence in controlling surface erosion and reducing soil loss. These results demonstrated that the combined application of natural geotextile and bio-grout can provide an effective measure in slope protection against erosion.

Keywords: Geotextile, Pineapple leaves, Luffa, Soil erosion, Bio-grout

1. INTRODUCTION

Soil erosion is considered a worldwide problem that affects agriculture and the surrounding environments. The rate and magnitude of soil erosion is greatly influenced by rainfall intensity and runoff, soil erodibility, slope gradient and length and vegetation. Deposition of eroded mass materials can cause damage to roadways and drainage channels [1]. Soil erosion can be avoided by applying a protective cover on the soil to create a barrier to the erosive agent and by altering the physical properties of the soil through chemical grouting and mechanical means.

Geotextiles are permeable fabrics used in association with soil or earth for separation, filtration, drainage, reinforcement and protection to enhance the engineering performance of soil structure. The usage of geotextiles in road construction and soil erosion control dates all the way back to the first millennium BC where the roads were reinforced with geotextiles made of natural fibers [2].

In soil erosion control, geotextiles act as a protective cover and help to stabilize the soil surface by minimizing the effect of soil erosion caused by erosive agents such as water and wind. Geotextile can be synthetic or natural. Geosynthetics are mostly made up of polymeric products such as polyamide and polyethylene sourced from hydro-carbon and petrochemicals. The manufacturing of these materials somehow contribute to greenhouse effects and carbon dioxide emission which is now a global concern [3]. Geosynthetics are more commercialized and extensively used because of its wide range of applications in solving geotechnical problems.

However, in the long run, this can lead to environmental pollution due to the accumulation of plastic debris from the polymers that are non-destructive which may have direct impact on the ecology. On the contrary, geotextiles from natural fibers are affordable, environmental friendly and bio-degradable in nature. The natural fibers will degrade and subsequently turn into organic compost and blend with the soil, thus providing nutrients for growth of vegetation and promoting soil microbial activity [4]. Some of the natural fibers used for geotextiles include jute, coconut, sisal and coir which are abundantly available in tropical countries such as India and Pakistan.

Geotextiles made of jute, for example, were effective in improving the soil characteristics and have been used extensively in various technical applications. Natural geotextiles are increasingly used in geotechnical applications due to the growing effort of extensive research. Nevertheless, the usage of natural fiber geotextiles is still relatively small, constitute only less than 10 % of the present global consumption [5].

In recent years, many studies on bio-grout were carried out by several researchers for soil improvement and concrete repair [6]. Bio-grouting is a new ground improvement technique in geotechnical engineering practice based on microbial carbonate precipitation (MCP) that can change the mechanical properties of soil. MCP refers to a bio-mechanism process involving microbial activities and bio-chemical pathways such as denitrification, ureolysis and ammonification [7]. The end-products resulted in mineral precipitation that helps bind soil particles together through bio-clogging or bio-cementation process. This helps to improve the texture by filling the voids within the soil matrix that eventually increase the strength and stiffness of the soil. Many studies have reported that the MCP method is very effective in increasing the shear strength and decreasing the permeability of sandy soil [8-9].

In laboratory studies, specific ureolytic bacterial strain such as *Sporocarcina pasteruii* has frequently been used to induce microbial calcite precipitation. This bacterium plays an important role in producing calcium carbonate ($CaCO_3$) precipitation through urea hyrolysis. For bio-cementation or bio-mineralization to occur, urea and calcium chloride ($CaCl_2$) are needed to provide the necessary nutrients [10-11]. Other studies on bio-calcification have used other alternative medium such as chicken manure affluent as a good source of nutrients to promote bacterial growth for microbial cementation because large scale experiments of MCP process can be costly [12].

Another innovative study by our research team has demonstrated that bio-grout from vegetable waste can also improve the engineering properties of liquefied soil by increasing the soil shear strength and reducing soil permeability through the microbial activities in the bio-grout fluid [13]. Apart of that, the bio-grout was also proven to be an effective grouting material for soil erosion control as demonstrated using slope models [14].

In view of the above, combined applications of natural geotextile made of pineapple leaves and bio-grout from vegetable waste may provide sustainable and economical solutions for soil reinforcement and slope stabilization compared to that of chemical and mechanical methods. This new design can promote the reusing and recycling of agricultural waste that can benefit the economy. The main objective of this research was to observe and monitor the effectiveness of the combined methods of bio-grout injections and geotextile from pineapple leaves with respect to soil erosion on the slope surface.

2. EXPERIMENTAL

2.1 Experimental site

The soil sample was collected at the College of Engineering, Universiti Tenaga Nasional (UNITEN) adjacent to a drainage system where a slope failure has occurred (Figure 1). The slope surface has undergone soil erosion due to rainfall impact. The sample was taken at the center of the slope, at 70 m elevation. Sample was taken using a cylindrical tube measuring 38 mm and 60 mm in diameter, at a depth less than 1.5 m. The soil was classified as sandy SILT with intermediate plasticity. The liquid limit of the soil was 38.38%. The liquidity index (LI) of the soil where the relative consistency of a cohesive soil in natural state was -0.31 which was less than 1. The soil was well graded and has a high percentage of fine grained particles of more than 50% (63.74%). The data for soil sample is summarized in Table 1.

Fig. 1 Experimental site

Table 1 Basic properties of soil sample

Properties	Values
Soil Type	Sandy SILT
Group Symbol	ML
Gravel fraction	2.82 %
Sand fraction	33.45 %
Silt fraction	63.74 %
Coefficient of uniformity	19.74
Coefficient of gradation	2.75
Specific gravity	2.71
Liquid limit	38.38 %
Plastic limit	30.88 %
Plasticity index	7.5
Liquidity index	-0.13(<1)
Moisture content	29.9 %

2.2 Geotextile material and design

In this study, the natural geotextiles were constructed from pineapple leaves and luffa. Pineapple or locally known as ‘Nanas’ is a tropical plant native to South East Asia and Malaysia is one of the major producers [14-15]. Pineapple leaf is rich in cellulose and biodegradable. A study on pineapple leave fiber showed that they are suitable for building and construction materials due to its highest cellulosic content [16-17].

Luffa acutangula is extensively used throughout the world as hybrid biodegradable composites. Luffa is high water permeability, low cost and biodegradable [18]. It has a thick texture that prevents the water to pass through easily. Luffa was added to strengthen the structure of the geotextile by providing open grid like configuration to support the pineapple leaves.

Factors that affect the construction of geotextile include the type of seam, seam location, type of stich and thread, and the number of row of stitching [19]. The type of seam is important to develop a good strength for the geotextile. The common seam types are S-seam and J-seam. The S-seam combines two sections of fabrics with one or more rows of stitching. The J seam type was done by overlapping two parts of fabric and folding them to produce a thickness of four plies. This type of seam has more strength com-pared to other type of seam. The strength of seam can also be affected by the placement of seam. For fabric geotextile, the seam is sewn 1 to 1.5 inches from the edge and folded to create a double plies thickness.

In this work, the design of the geotextile from pineapple and luffa followed the J-seam type that was previously described [20]. The geotextile layers of dried pineapple leaves were assembled together with luffa fabric and sewn using jute yarn that has a diameter of 1.2 mm. See Fig.2.

Fig. 2 Geotextile from pineapple leaves and luffa

2.3 Geotextile application

In this study, the natural geotextile was assembled as surfacing to prevent the removal of soil particles from the soil surface. At the site, the geotextiles were arranged following the grid concept for monitoring and analysis purposes. Three grids were assigned as shown in Fig. 3. Grid A represented a control grid which did not have any bio-grout or geotextile (negative control). In grid B, the soil was treated with bio-grout only, and in grid C, both bio-grout and geotextile were combined together. The observation and monitoring of the slope surface at the site was carried out every seven days for five weeks. Fig. 4 shows Grid A, B and C on the first day of geotextile and bio-grout application.

Grid	GRID A	GRID B	GRID C
Biogrout	NO	YES	YES
Geotextile	NO	NO	YES

Fig. 3 Grid distribution

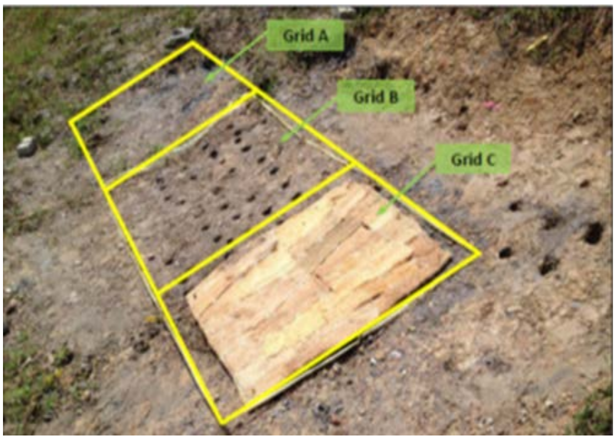

Fig. 4 Application on day 1

2.4 Preparation of bio-grout

The bio-grout was obtained through the fermentation process of mixed vegetable waste consisting of spinach, cucumber, water spinach, long bean and cabbage as previously described [21]. The vegetable wastes were fermented for one month. After that, the extract was filtered to get the bio-grout fluid. The flow chart of the overall process is shown in Figure 5. The bio- grout contained the essential elements such as silica, iron and calcium needed for the bio-cementation process. These elements are essential for the production of construction biomaterials in bio-technological processes [22]. Figure 6 shows the extract of bio-grout liquid after fermentation process.

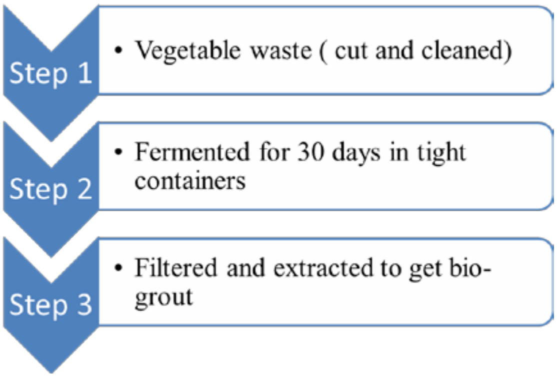

Fig. 5 Process of bio-grout preparation

Fig. 6 Bio-grout liquid

2.5 Grouting method

The bio-grout in liquid form was injected into the ground using gravity. PVC (polyvinyl chloride) pipe with 25 mm in diameter was cut into 1 m length. Small holes were drilled on the pipes (5 mm apart) to allow the bio-grout to flow out in parallel during the grouting process. The pipes were inserted into the soil about 500 mm to 700 mm in depth and each grid consisted of 11 pipes (Fig. 7). The grouting rate was approximately 1.8 mL / s or 30 minutes per liter. Overall, 45 liters of bio-grout liquid were used in the grouting process.

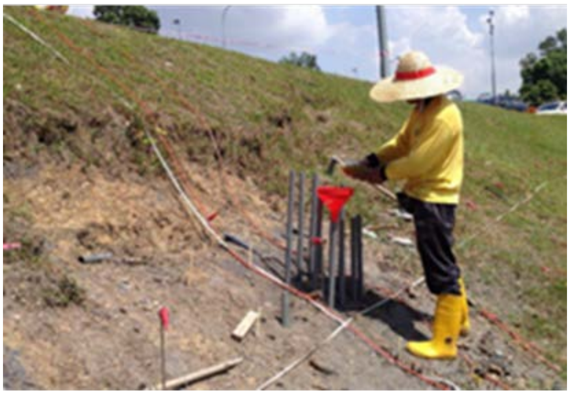

Fig. 7 Bio-grout injection using by gravity

3. RESULTS AND DISCUSSION

After 28 days, observation showed that new batch of grass has grown in grid B and C that had bio-grout injected compared to that of Grid A (Fig. 8). The geotextile in Grid C has undergone natural degradation process throughout the experimental period but the soil underneath the geotextile layer did not show any significant sign of further erosion. There were large amounts of trapped soil and small gravel underneath the geotextiles. The geotextiles did not degrade quickly, thus giving ample time for the surface of the soil to be stabilized again. Furthermore, degraded natural geotextile promotes new vegetation and contributes to the soil nutrients through microbial activity [22].

On the contrary, the slope surface in grid A and B were slightly eroded. The minimum optimum curing time was observed on day 21 after the bio-grout treatment. After 35 days of treatment, Grid B was fully covered by grass compared to that of Grid A. In grid C, the geotextile has degraded by 95% and the surface was partially covered by grass as shown in Figure 9. There was no significant sign of soil erosion in Grid B and C.

Implementation of bio-grout has encouraged microbial activity in the soil to induce bio-mineralization and simultaneously increase the content of organic matter resulting in the increases in biomass that will spur the growth of vegetation cover. The structure of soil and soil fertility were improved because of the greater availability of nutrients and organic substance. Bio-grout from vegetable waste has the potential to replace chemical stabilizers due to the presence of indigenous bacteria as well as mineral contents that can induce the bio-cementation and bio-clogging process between the sand particles. The application of bio-grout treatment and geotextile from pineapple leaves and luffa helped supported the growth of grass and reinforced the slope surface from erosion.

Fig. 8 Observation of Grid A, B and C on day 28

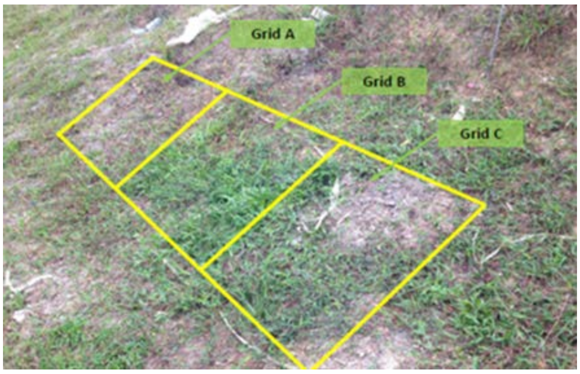

Fig.9 Observation of Grid A, B and C on day 35

4. CONCLUSION

This research was focused on the application of both techniques; geotextile and bio-grout from agriculture waste as an innovative way in controlling soil erosion. Observations showed that the treated soil has significantly improved and soil erosion was controlled and prevented. The natural geotextile from pineapple leaves and luffa has contributed significantly by providing protection and long term stability to the soil surface. The geotextile from pineapple and luffa is not susceptible to quick degradation and more durable, thus permitting vegetation to grow in shorter time. In addition to that, the soil properties was also enhanced and improved with the introduction of bio-grout from vegetable waste that help increase the organic matter in the soil.

The combined techniques has successfully protected the slope surface from erosion and enhanced the soil stability. This study showed that the combined application of natural geotextile from pineapple leaves and bio-grout from vegetable waste offers an alternative method to current geotechnical methods for slope stability. The use of natural fibers from plants and agriculture waste is more sustainable, renewable, cost effective and energy efficient. In future study, more tests will be carried out to evaluate the engineering properties of the treated soil.

4. ACKNOWLEDGEMENTS

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