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The Performance of Vetiver Root Growth with EM.PB and Coconut Fibre-Physical Model

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ABSTRACT

Slope failure can cause serious problems such as infrastructure damage or death. Vegetation is one of the applications used to improve slope stability. The problem is that sloping failure still occurs due to a lack of shear strength or tension in the soil. This research aims to overcome the failure with the objective of identifying the morphology and properties of the Vetiver roots, measuring the shear strength and root tensile strength in the presence of EM.PB and comparing two different planting methods of vetiver grass. A direct shear test and a tensile test were conducted after one month and two months to find the strength of the vetiver root that has been planted in PVC pipe. After 2-months, the average Vetiver root growth with EM.PB has the highest value which is about 111.9 cm compared to planting with EM.PB and coconut fibre which obtained 92.88 cm. For shear strength, after one month of planting, the results of vetiver grass with EM.PB and coconut fibre had the highest value with 1.4936 N/mm^2 compared to vetiver with EM PB with a value of 1.3671 Nmm^2. While after two months, the highest value is 1.4936 N/mm^2 with coconut fibre and without coconut fibre is 1.4916 N/mm^2. Planting in EM PB and coconut fibre can improve the soil's shear strength, in contrast to the tensile strength data. By adding EM.PB solution to the soil, it can promote the development of vetiver grass roots, which can act as reinforcement for slope stabilization.

1. Introduction

A slope is an inclined soil mass surface, and they can be created by nature or by humans [3,10]. Investigations into the slope's shear strength, balance, and ability to withstand movement are particularly crucial to minimize slope failure. Slope failure occurs when a slope collapses due to the soil's inadequate ability to support itself, which results from rainfall, earthquakes, and other natural factors [6,12,17,19,27]. Translational failure, compound failure, wedge failure, and rotational failure are the four types of slope failure that can occur on a site [5,13].

Vegetation can be said to a thing that helps in the stability of a slope by making the vegetation reinforce and strengthen the structure of the slope [1,16,18]. But the strength will vary according to

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the character of the plant morphology used as well as the strength of the plant roots themselves to withstand the load [4,11,15]. The use of vegetation for slope stabilization is already exist to some countries out there and there are studies that have been conducted to investigate the strength of the vegetation on the soil.

This vegetation has many effects on the soil such as tensile strength and shear for example. According to [4] in a study conducted by them in August 2008, "Shear Strength of a soil containing Vegetation Roots, an increase in cohesion to the soil can be seen as the roots of the plant lengthen and this shows that the plant roots respond to cohesion and this depends on the length the root grows". It can be concluded here that the use of vegetation can help in increasing shear strength in soil. In addition, the use of vegetation can also control erosion to the soil by acting as a medium of water absorption [1,3,6,8,9,20-26]. Saturated soil can result in landslides. With the presence of vegetation, it can get rid of the volume of water that does not need to be used for the soil and it able stabilize the soil condition.

1.1 Slope Failure in Malaysia

According to the study, which is a preliminary investigation into the slope failure at highland in peninsular Malaysia, excessive infiltration brought on by strong rainfall would cause clay particles in the soil structure to swell and cause slope failure [6]. Clay swells and turns porous when it is exposed to water for a long time. In this circumstance, the clay's ability to bind would diminish, weakening the remaining soil structure. A landslide would occur as a result of the collapse of slope stability brought on by the loss of soil strength. Slope failure can be caused by improper slope design, inadequate maintenance, soil type, and gradient slope [2]. A landslide caused by slope failure in Bukit Antarabangsa in December 2008 resulted in 20 more landslides and the deaths of several residents [7].

1.2 Application of Vetiver Grass

To minimize landslides and erosion, vetiver grass was planted on the banks in the form of terraced plantings, which also helped to catch silt during rainwater runoff. Although vetiver grass has less moisture in its roots than Bermuda grass, which is bad for tensile strength where the value needs to be high, Vetiver grass may survive during periods of heavy rain better than Bermuda grass [4]. By transferring shear stress from the soil matrix to tensile inclusions, vetiver roots strengthen the soil. The root matrix increases the soil's shear strength. The interaction between the soil and roots produces a composite material in which the roots are fibres with a relatively high tensile strength, and here is where vetiver roots play a significant function as a medium to raise the strength of the soil [14].

In the tropics, the usage of vetiver grass (Chrysopogon zizaniodes) has been commercialized as an economical and environmentally responsible method of slope stabilisation and erosion prevention. A straightforward technique or practical known as the vetiver system can be employed to aid in soil stabilisation, sediment control, or even water conservation for the soil. On the banks of the land, vetiver grass sown in stages can increase stability and reduce water permeability. The World Bank first introduced the use of vetiver grass as a slope protection method in India in the 1980s [6].

1.3 EM.PB Solution for Agriculture Purpose

Strong phototropic bacteria are present in the EM.PB solution. Light is the source of Energy for phototropic bacteria, which are widely distributed in nature. harmless to the environment and non-toxic. These microorganisms produce metabolites, which are readily absorbed by plants. These microorganisms operate as nitrogen binders and multipliers of other microorganisms. The benefits of EM.PB include its ability to improve soil and water quality. Aside from that, it able to promote healthy plant growth.

1.4 Coconut Fibre for Planting

Coconut fibre usually known as a waste product of the coconut industry and was used as a growing medium. Besides, coconut fibre is an environmentally sound peat substitute in soilless growing medium for crop production due to the suitable physical and chemical properties. Coconut fibre might be an alternative, renewable, and reliable growing media for planting because the coconut fibre had a plant growth-promoting bacteria (PGPB) that can enhance plant growth and protect plants from disease and abiotic stresses. Composting of coconut coir dust increased the number of lignin and cellulose degradation bacteria; moreover, it indicated that coconut coir dust is potentially for growing medium with high activity of plant growth promoting bacteria [24]. In this study, the coconut fibre and EM PB were applied to enhance Vetiver root reinforcement for slope stabilization in order to minimize the landslides occurrence.

2. Methodology

For root mechanical properties, the experiment that has been conducted is direct shear stress test. The effectiveness of vetiver grass as well as EM.PB solution was seen through the results of shear test.

2.1 Determination of Root Properties

Root properties were evaluated such root morphology, root diameter and root length. To obtain the root properties, vetiver grass is planted as shown in Figure 1. The equipment that was used for physical modelling include PVC, soil, vetiver grass, EM PB chemical and hand shovel. The PVC pipe was cut to a predetermined length of 500mm. Then, soil was inserted into PVC using a hand shovel. The space for the vetiver grass was left. The vetiver grass was placed vertically inside the PVC and added soil until the roots were covered. Sample divided into two categories where EM.PB solution(disturbed) with percentage of 5% and 10% and the other one without solution added (undisturbed). After 1 month and two months of planting, three samples of root were brought to the laboratory to run the test.

Fig. 1. Vetiver grass was planted in PVC pipe – Physical Modelling

2.2 Direct Shear Test

The equipment that was used in this test are shear box container, base plate with cross groves on top, porous stone, plain grid plate, perforated grid plates, loading pad, weighing, load frame, dial gauge, tampering rod, spatula, rammer, proving ring and samples. For this testing, the soil was divided into three parts. The sample was put aside first and the shear test apparatus was set up first. The readings were recorded for every 20 drops until three constant readings are obtained. The loading started with 2kg of load. The shear box was unlocked, and the procedure was repeated for 4kg and 6kg load. The data was put on the table to calculate the shear stress, normal shear and then the graph was plotted to obtain cohesion, friction angle and lastly shear strength by using formula. The shear strength is equal to the sum of the normal stress (σ) and cohesion (c). The Mohr coulomb equation is shown as below in Eq. (1):

$$Shear\ Strength\ (T) = C + \sigma n\ tan\theta \qquad (1)$$

3. Results

The experiment was carried out after the planted vetiver grass had enough planting time accordingly. The study that has been conducted is direct shear test.

3.1 Root Properties Determination

Root properties were done measured such as root morphology, root diameter and root length shown in Figure 2. The root length of grass was measured every once a week and the data were recorded. Table 1, 2, 3, and Table 4 show the average root length of vetiver grass. The highest root length recorded is 70.2 cm. Root length was found increased by 30 to 60 % per month for every type of sample. For control sample with 0% of EM.PB solution, the highest average root length is about 68.7 cm. For sample with 5% of EM.PB solution, the highest average root length is 69.3 cm. And with 10% solution, the highest average root length is 70.2 cm. For the first week, all Vetiver grass grew over 15 cm with the average of 21.5 cm.

From Table 2, the highest average root length of Vetiver grass with the 10% of EM.PB solution is 111.9 cm. Average root growth for control sample is 100 cm per month. For uncontrol sample, the highest average root length for 5% and 10% EM.PB solution is 109.5 cm and 111.9 cm respectively. The Vetiver root length is higher when the EM.PB solution are added per week. From the result obtained, it shows that the presence of EM.PB solution helps in vetiver growth.

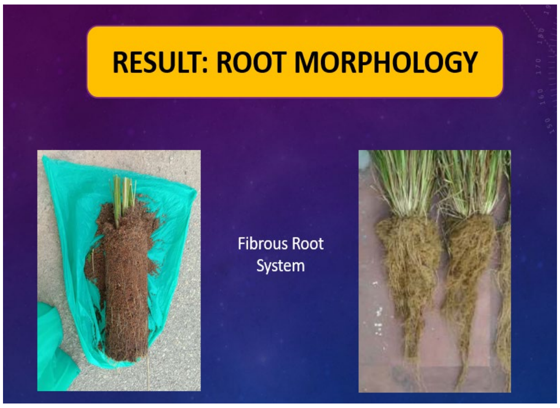


Fig. 2. Determination of root morphology

Table 1
Average root length of Vetiver grass for 1 month planted

EM.PB Solution (%)	Week	Average Root Length (cm)
0	1	15.6
	2	28.3
	3	46.6
	4	68.7
5	1	24.6
	2	41.0
	3	61.7
	4	69.3
10	1	24.2
	2	51.7
	3	59.1
	4	70.2

Table 2
Average root length of Vetiver grass for 2 months planted

EM.PB Solution (%)	Week	Average Length growth (cm)	Week	Average Root Length (cm)
0	1	16.5	5	79.4
	2	30.0	6	85.7
	3	49.4	7	92.6
	4	72.8	8	100.0
5	1	26.1	5	80.1
	2	43.5	6	88.9
	3	65.4	7	98.7
	4	73.5	8	109.5
10	1	25.7	5	79.6
	2	54.8	6	89.2
	3	62.6	7	99.9
	4	74.4	8	111.9

Table 3 shows the average root length Vetiver grass with the presence of coconut fibre for 1 month period of planted. The average root length for a control sample with 0% EM.PB solution is about 58.40 cm. The average root length for the sample containing 5% EM.PB solution is about 58.91

cm. Additionally, with a 10% EM.PB solution, the overall average root length is about 59.67 cm. Every vetiver grass grew more than 10 cm within the first week.

Table 3
Average root length of Vetiver grass for 1 month planted with coconut fibre

EM.PB Solution (%)	Week	Average Root Length (cm)
0	1	13.26
	2	24.06
	3	39.61
	4	58.40
5	1	20.91
	2	34.85
	3	52.45
	4	58.91
10	1	20.57
	2	43.95
	3	50.24
	4	59.67

Table 4 displays the average root length of Vetiver grass for 2 months planted period with coconut fibre. For control sample with 0% EM.PB solution, the highest average root length is about 83.00 cm. For an uncontrol sample, the highest average root length of Vetiver grass is about 90.89 cm and 92.88 cm for 5% and 10% EM.PB solution. The Vetiver grass with 10% EM.PB solution obtained highest average root length compared to other percentage of EM.PB solution. When the EM.PB solution is added weekly, the Vetiver grass grows more quickly. The outcome indicates that the presence of EM.PB solution promotes the growth of Vetiver.

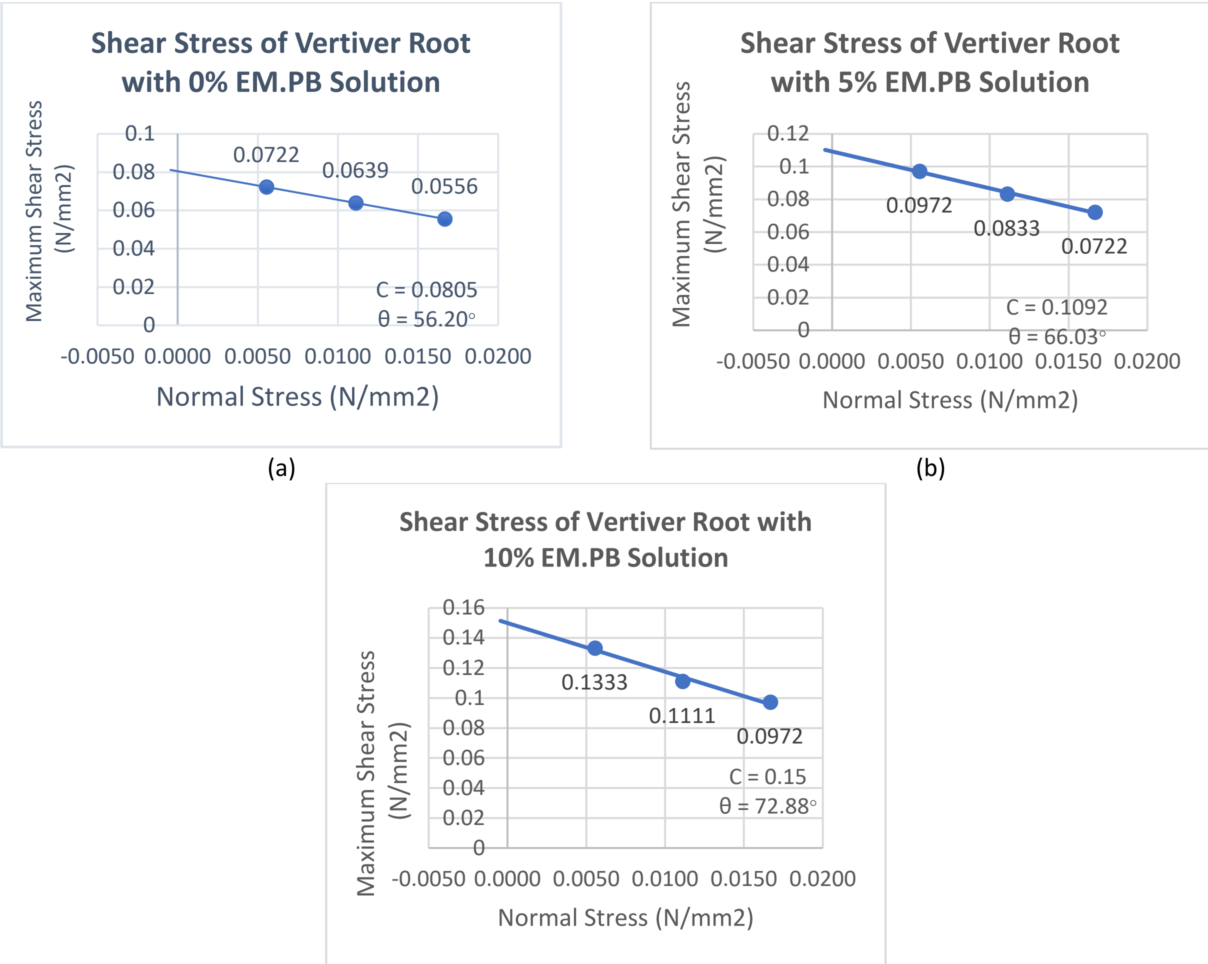
Table 4
Average root length of Vetiver grass for 2-months planted with coconut fibre

EM.PB Solution (%)	Week	Average Root Length (cm)	Week	Average Root Length (cm)
0	1	13.695	5	65.90
	2	24.9	6	71.13
	3	41.002	7	76.86
	4	60.424	8	83.00
5	1	21.663	5	66.48
	2	36.105	6	73.79
	3	54.282	7	81.92
	4	61.005	8	90.89
10	1	21.331	5	66.07
	2	45.484	6	74.04
	3	51.958	7	82.92
	4	61.752	8	92.88

3.2 Direct Shear Test

Direct shear test was performed with three (3) different conditions where each sample had a different value of additives and value of loading. Figure 3 and 4 show the value of shear stress for 1 month planted and Figure 5 and 6 show shear stress value of sample after 2-months planted with only soil and addition of EM.PB solution. Each graph represents the result with a different amount of EM.PB solution added. Data from the graph were calculated to obtain shear strength value.

For a sample with 0% EM.PB solution, the cohesion obtained from graph Figure 3 (a) is about 0.0805 kPa with friction angle,56.20^0. While, the highest maximum shear stress obtained is 0.0722 N/mm^2. From graph Figure 3 (b) with 5% EM.PB solution, the cohesion obtained is about 0.1092 kPa with friction angle, 66.03^0 and the highest value for maximum shear stress is 0.0972 N/mm^2. From the graph Figure 3 (c), the value cohesion is obtained which is 0.15 kPa with friction angle,72.88^0. The highest maximum shear stress is about 0.1333 N/mm^2.



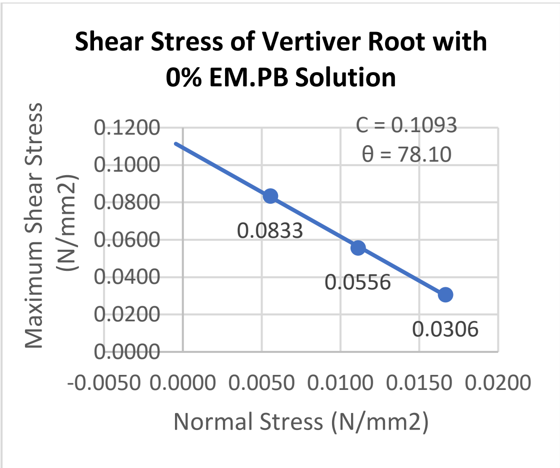
(c)

Fig. 3. Shear strength analysis after 1-month planted

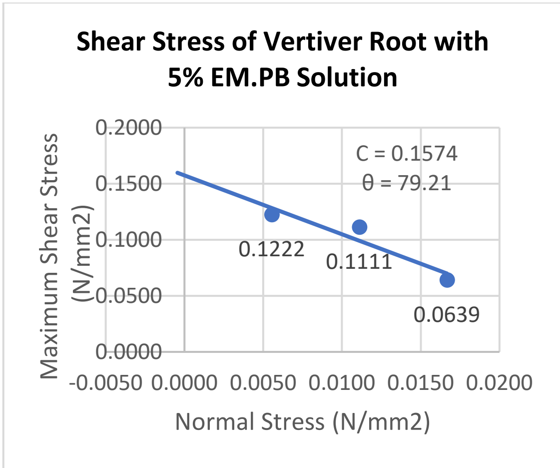
Figure 4 shows show the value of shear stress for 1 month planted. For a sample with 0% EM.PB solution, the cohesion and highest maximum shear stress obtained from graph Figure 4 (a) is about 0.1093 kPa with friction angle, 78.10^0. From graph Figure 4 (b), the cohesion obtained is about 0.1574, and the greatest value for maximum shear stress is 0.1222 N/mm^2 with friction angle, 79.21^0. The value of cohesion is 0.2102 kPa, as shown by the graph Figure 4 (c) with 0.1944 N/mm^2 for the highest maximum shear stress with friction angle, 76.73^0.

Figure 5 shows the graph of shear stress for Vetiver root that was planted with soil, coconut fibre and addition of EM.PB solution for 1 month period. For a sample with 0% of EM.PB solution shown in Figure 5(a), the cohesion obtained is about 0.0731 kPa with friction angle, 44.99^0 and the highest value of maximum shear stress for the soil is 0.0667 N/mm^2. From graph Figure 5 (b), the cohesion for the soil sample is 0.1093 kPa and the highest value for maximum shear stress is 0.0889 N/mm^2 with friction angle, 71.56^0. From the graph Figure 5 (c), the cohesion obtained id about 0.1676 kPa with 0.13333 N/mm^2 value of maximum shear stress.

Figure 6 shows the result of shear stress for vetiver root with the presence of coconut fibre and soil after 2 months period. From Figure 6 (a), for control sample the cohesion value obtained is about 0.087 kPa with 0.0889 N/mm^2 of maximum shear stress and friction angle, 44.99^0. From graph Figure 6 (b), with the presence of 5% EM.PM solution and coconut fibre the cohesion obtained is about 0.1296 kPa with maximum shear stress value, 0.1167 N/mm^2 and friction angle, 71.56^0. While, the value of cohesion obtained with presence of 10% EM.PB solution and coconut fibre is about 0.2121 kPa, as shown by the graph (c) with 0.1944 N/mm^2 of maximum shear stress and friction angle, 76.74^0.



(a)



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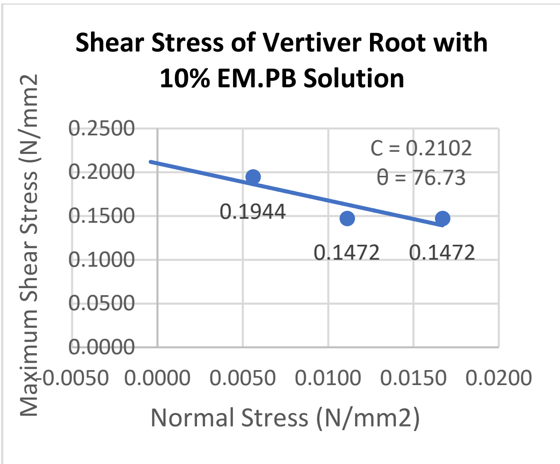

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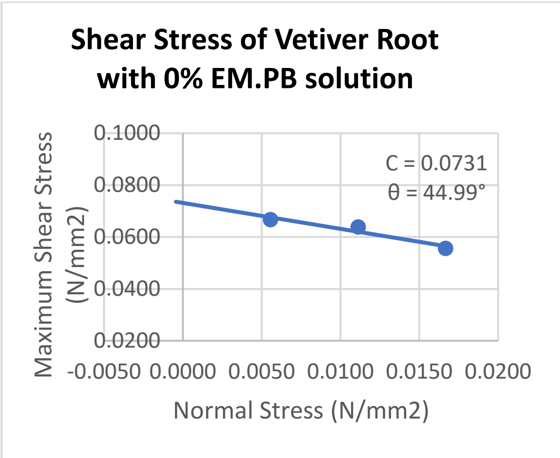
Fig. 4. Shear strength analysis after 2-month planted.



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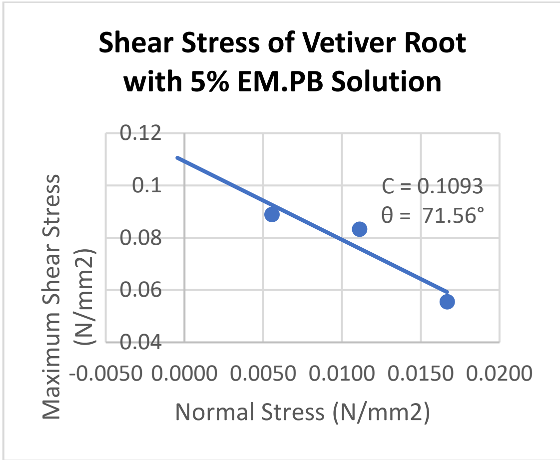

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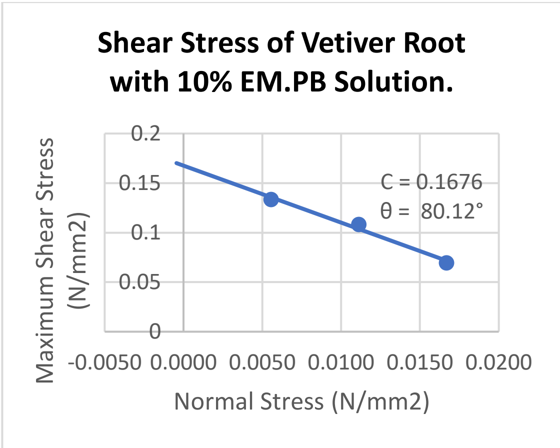

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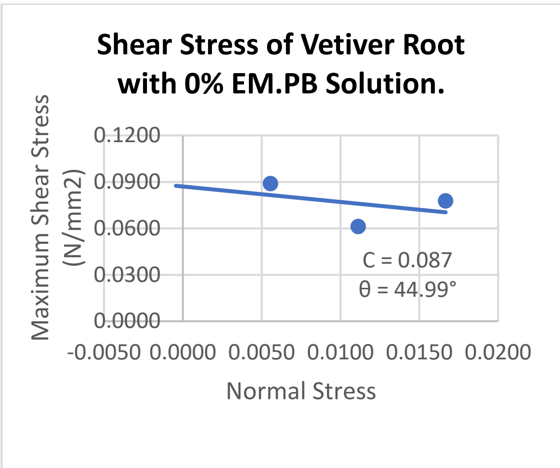
Fig. 5. Shear strength analysis after 1-month planted



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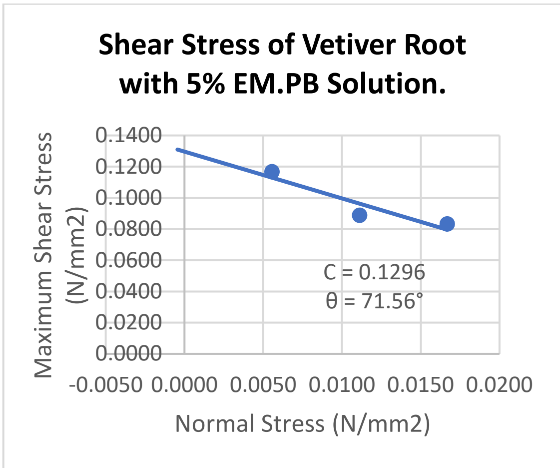

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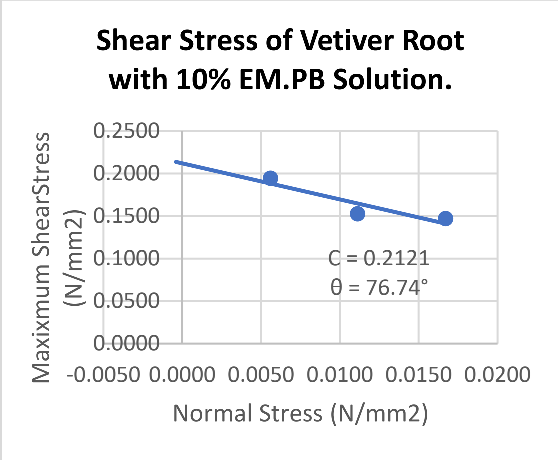

(c)

Fig. 6. Shear strength analysis after 2-month planted

Based on the results obtained, the value of shear stress is higher when the additive solution is added. This could be seen from the different findings between 0% of EM.PB solution and 10% of EM.PB solution added during planting.

Table 5 and Table 6 shows the comparison of data between Vetiver grass with soil and soil that is mixed with coconut fibre. From the Table 5, with 0% of EM.PB solution, the highest shear strength obtained is 1.019 N/mm^2 which is Vetiver root with soil only. For Vetiver root with 5% and 10% EM.PB solution, the highest shear strength obtained is about 1.3043 N/mm^2 and 1.5057 N/mm^2 respectively with the presence of coconut fibre.

Table 5
Value of shear strength result after 1 month planted

EM.PB Solution (%)	Load (kg)	Sample Part	Vetiver Root with Soil and coconut fibre		Vetiver Root with soil	
			Max Shear Stress (N/mm^2)	Shear Strength (N/mm^2)	Max Shear Stress (N/mm^2)	Shear Strength (N/mm^2)
0	2	Top	0.0667	0.8245	0.0722	1.019
	4	Middle	0.0639	0.5725	0.0639	0.743
	6	Bottom	0.0556	0.3251	0.0556	0.3952
5	2	Top	0.0889	1.3043	0.0972	1.2119
	4	Middle	0.0833	0.9036	0.0833	0.8421
	6	Bottom	0.0556	0.51	0.0722	0.479
10	2	Top	0.1333	1.5057	0.1333	1.3671
	4	Middle	0.1083	1.057	0.1111	0.959
	6	Bottom	0.0694	0.6163	0.0972	0.5581

Table 6 shows the result of Vetiver grass after 2-month planted. From the Table, with 0% of EM.PB solution, the highest shear strength obtained is 1.4136 N/mm^2 which is Vetiver grass plant with soil only. For vetiver grass with 5% of EM.PB solution, the highest shear strength is 1.4802 N/mm^2 and for 10% solution, highest value is 1.4936 N/mm^2.

Table 6
Value of Shear strength result after 2-months planted

EM.PB Solution (%)	Load (kg)	Sample Part	Vetiver Root with soil and coconut fibre		Vetiver Root with soil	
			Max Shear Stress (N/mm^2)	Shear Strength (N/mm^2)	Max Shear Stress (N/mm^2)	Shear Strength (N/mm^2)
0	2	Top	0.0889	0.8384	0.0833	1.4136
	4	Middle	0.0611	0.5864	0.0556	0.9762
	6	Bottom	0.0778	0.339	0.0306	0.5467
5	2	Top	0.1167	1.3246	0.0639	1.4802
	4	Middle	0.0889	0.9239	0.1222	1.0366
	6	Bottom	0.0833	0.5303	0.111	0.601
10	2	Top	0.1944	1.4936	0.1944	1.4916
	4	Middle	0.1528	1.0639	0.1472	1.0619
	6	Bottom	0.1472	0.6418	0.1472	0.6399

According to the findings, adding the additive solution increases the shear strength value. This was evident from the disparate results between the addition of 0% EM.PB solution and 10% EM.PB solution during planting. The Vetiver root with the presence of coconut fibre and soil shows higher value of shear strength compared to only soil with the increases of planted period. Planting with coconut fibre does help in increasing the shear strength of the soil with the help of EM.PB solution.

4. Conclusions

The results from the shear stress test indicate that the presence of the EM.PB solution contributes to enhance the strength parameters value. Based on the findings, the bottom part of the root has lower shear stress resistance compared to the top and middle bottom. The shear strength decreases as the root section gets smaller. As for the vetiver grass plant with addition of coconut fibre, after extending the planting period, the vetiver grass plant with soil and coconut fibre exhibits more shear strength than the one with soil only. The soil's shear strength can be increased by planting with coconut fibre. The application of EM.PB solution to the soil can be seen as an additional chemical that improves agriculture while also promoting the growth of Vetiver roots, which can work as reinforcement for slope stabilization.

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