A Tensile Strength of Bermuda Grass and Vetiver Grass in Terms of Root Reinforcement Ability Toward Soil Slope Stabilization

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Abstract. An examination on root characteristics and root properties has been implemented in this study. Two types of bioengineering were chose which are Vetiver grass and Bermuda grass as these grasses were widely applied for slope stabilization. The root samples were taken to the laboratory to investigate its classification, characteristics and strength. The root of both grasses was found grow with fibrous root matrix system. In terms of root anchorage, the root matrix system of Vetiver grass was exhibits more strengthen than the Bermuda grass. However, observation on root image from Scanning Electron Microscope test reveals that the root of Vetiver grass becomes non-porous as the moisture content reduced. Meanwhile, the root tensile strength of Bermuda grass was obtained acquired low value with higher percentage of moisture content, root morphology and bonding strength. The results indicated that the root tensile strength is mainly influence by percentage of moisture content and root morphology.

Keywords: Bioengineering, root morphology, slope stabilization.

1. Introduction

Nowadays, the slope failure is the most frequently phenomena occurred on Earth. The geotechnical engineer always faces a problem especially with shallow failure. Shallow failure which estimated about at depth about 1 to 1.5 meters is still under aware solving problem. There is none a good option to mitigate the slope failure until today. Apart from that, bioengineering technique which is vegetation cover was usually applied for mitigation the slope failure because its advantages. The technique is less cost, fast grows and easily planted. Generally, the vegetation mainly stabilizes the slope by mechanical effects through root matrix system [5,4, 13,9,8,7,12,11,14-1]. The soil shear strength is found increase through the mechanical effects of the vegetation root matrix system where the root acts as reinforcement toward the soil. [6,4,13,9,10,7,2,3,12,15-1]. In Malaysia environment, Bujang and Sina [3]stated that the vegetation can potentially provide immediate mechanical shear strength for slope remedial and long-term beneficial effects. There are three common types of root morphology; heart root system (fibrous root system), tap root system (horizontal and vertical root system) and plate root system (horizontal root system) [10]. The definition of root morphology is architecture, shape or structure of vegetations root system [2]. In this study, new concept of root matrix system was introduced shown in Figure 1.
The Vetiver grass is very strong with high mean tensile strength of 75 MPa at 0.7 to 0.8 mm root diameter which is approximately 1/6TH of strength of mild steel [5]. Bermuda grass also has being good vegetation for protection slope. However, to date the slope failure is still happen although the slope has been covered with these grasses. This study shall investigate the main factors influence the vegetation root toward slope failure.

2. Materials and Methods

2.1 Site Characteristics and Grasses Types
The site investigation was carried out on well grown of Vetiver grass and Bermuda grass at cut slope gradient 450 which is at Maran area. The soil classification using Sieve analysis test was conducted based on British Standard 1377: Part 2: 1990: Clause 9.2.2. The soil and root samples were taken to the laboratory to study its characteristics and properties. Vernier Caliper was used to measure the root diameter and root length of both grasses as shown in Figure 2. The measurement unit was recorded in mm (millimeter). Besides that, the root morphology also was characterized by based on [10] findings.

![Figure 1](image1.png)

**Figure 1.** New concept of root matrix system was introduced in this study.

![Figure 2](image2.png)

**Figure 2.** Photographs of root measurement using Vernier Caliper.

2.2 Root Tensile Strength Test
The Bermuda grass and Vetiver grass root tensile strength test was conducted using Shimadzu Universal Testing Machine as shown in Figure 3. The test was conducted to determine the bonding strength between root matrix system of vegetation and soil. There are two stages of conducting the tensile strength test. For first stage, the root tensile strength was carried out on individual primary root...
and secondary root matrix system which is a group of 5, 10 and 15 roots. For second stage, the root samples were kept in the plastic to retain the moisture content. Then, the root was taken out to carry out the tensile strength test with following days; 1 day, 5 day, 10 day, 15 day and 20 day. The test was conducted on single individual of primary root matrix system. Besides that, the percentage of moisture content also was determined based on British Standard 1377: Part 2: 1990: Clause 9.2.2. The unit tensile strength of root sample was recorded in MPa (MN/m²).

Figure 3. Photographs of Root Tensile Strength Test using Shimadzu Universal Testing Machine

2.3 Scanning Electron Microscope (SEM) Test
A scanning electron microscope (SEM) is an electron microscope that produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that can be detected and display image of topography surface. SEM can achieve resolution better than 1 nanometer. The SEM test (Scanning Electron Microscope) was conducted to determine the texture of root after done second stage of root tensile strength test.

The root samples were examined with duration of 1 day, 5 day, 10 day, 15 day and 20 day. All samples must be of an appropriate size to fit in the specimen chamber and are generally mounted rigidly on a specimen holder called a specimen stub. Before begin the test, the root specimens were coated with gold (20nm) using a sputter coater (Emitech K550X) to prevent electron scattering as shown in Figure 4. Electron microscopic images of the root were recorded using a SEM (Hitachi) device with an accelerating voltage of 7 keV in high vacuum and secondary electron (SE) image mode.

Figure 4. Photographs of root specimens were coated with gold and images recorded using SEM Hitachi.
3. Results and Discussions

3.1 Root Morphology

Based on [10], the root morphology was characterized as heart root system which is growing with fibrous root system as tabulated in Table 1. The pattern of heart root matrix system of Vetiver grass and Bermuda grass is similar with geometry which is in semi sphere form. As mentioned before, the new concept of root matrix system has been introduced in this study shown in Figure 1. The root matrix system of Vetiver grass and Bermuda grass has three type of root system; primary root system, secondary root system and tertiary root system. It can be said that these grasses have a good anchoring toward slope.

3.2 Root Tensile Strength of Vetiver grass and Bermuda grass

The tensile strength test has been implemented on a group of 5, 10 and 15 for primary and secondary root system of Vetiver grass and Bermuda grass. The tensile strength toward root system was plotted in the bar graph as shown in Figure 6. It was observed that the Vetiver grass require maximum force rather than Bermuda grass to pull the root with results obtained; 5 primary root (138.56 MPa), 10 primary root (339.15 MPa), 15 primary root (431.07 MPa), 5 secondary root (181.91 MPa), 10 secondary root (238.52 MPa) and 15 secondary root (367.26 MPa) respectively represented by red bar from the graph. Meanwhile, for Bermuda grass the tensile strength for 5 primary root (181.12 MPa), 10 primary root (122.65 MPa), 15 primary root (460.74 MPa), 5 secondary root (52.98 MPa), 10 secondary root (71.74 MPa) and 15 secondary root (219.28 MPa).

Based on [5], it can be clarified that the values of root tensile strength for both grasses is more than 75 MPa which is can be considered very strong category of root system. To see whether the root matrix system for both grasses can be considered strong or not, the root system was further investigate through Scanning Electron Microscope test. The physical root system can be seen from the root texture image with respect to different percentage of moisture content. The root diameter and root length data were tabulated in Table 2.

Figure 7 and Figure 8 shows the relationship between root system and moisture content. For Bermuda grass, at day 1 the percentage of moisture content was recorded is 71.60% with tensile strength values ranged from 13.029 to 100.160 MPa. At day 20, the tensile strength gradually decreases by 16% while the moisture content increases by 14.3%. For Vetiver grass, it shows contrarily. At day 1, the percentage of moisture content was recorded 79.29% with tensile strength values ranged from 12.61 to 88.52 MPa. The tensile strength was found decreases as the moisture content decreases starting from day 5 to day 20.

It was observed that the root diameter and root length is not much influence the tensile strength of root system. Based on data obtained, it can be summarized that the heart root matrix systems for both grasses have good bonding strength toward the sandy soil slope. The individual root matrix systems are characterized by vegetation type where the degree of root development is varies within different type of vegetation. The root will grow through large pores if the soil has granular structure or sandy texture. Meanwhile, if the soil has clay or clay loam texture, the root will be confined to cracks. Drought condition and most nutrient deficiencies lead to limit root growth by slowing the growth of the shoot that supplies energy to the roots.
Table 1. Root morphology of Vetiver grass and Bermuda grass.

| Grass Types   | Root Morphology                      | Description                        |
|---------------|--------------------------------------|------------------------------------|
| Vetiver grass | Heart Root System (Fibrous)           | Geometry pattern: Semi-Sphere      |
| Bermuda grass | Heart Root System (Fibrous)           | Geometry pattern: Semi-Sphere      |

Based on Scanning Electron Microscope images, the root of Bermuda grass was found become more porous as the moisture content increases. The moisture content is easily absorbed by the root system through the pore space. Meanwhile, for Vetiver grass the root system become less pore space as compared at day 1. The less moisture content made the tensile strength of root system acquired low value.
Table 2. Root Diameter and Root Length for each grass.

| Grass type/ Growth Ranking | Root Matrix System   | Root Diameter (mm) | Root Length (mm) | Soil Classification                              |
|-----------------------------|----------------------|--------------------|------------------|---------------------------------------------------|
| Bermuda grass (Well grown)  | 5 primary root system| 1.04               | 80               | Sandy Soil                                        |
|                             | 5 secondary root system| 0.72              | 130              | Gravel 30.53 %, Sand 65.64%, Silt 3.83%           |
|                             | 10 primary root system| 1.01              | 140              | Slope gradient: 45°                               |
|                             | 10 secondary root system| 0.79            | 140              | Soil pH = 5.55                                    |
|                             | 15 primary root system| 0.89              | 130              |                                                   |
|                             | 15 secondary root system| 0.80            | 130              |                                                   |
| 1                           | Vetiver grass (Well grown) | 1.22            | 120              | Sandy Soil                                        |
|                             | 5 primary root system   | 0.53              | 90               | Gravel 30.53 %, Sand 65.64%, Silt 3.83%           |
|                             | 5 secondary root system | 1.24              | 120              | Slope gradient: 45°                               |
|                             | 10 primary root system     | 0.52              | 110              | Soil pH = 5.55                                    |
|                             | 10 secondary root system  | 1.09              | 100              |                                                   |
|                             | 15 primary root system     | 0.73              | 110              |                                                   |
|                             | 15 secondary root system  |                   |                  |                                                   |

Conclusion
The root morphology for Vetiver grass and Bermuda grass is fall into heart root system category which is growing with fibrous root system. It is a good root system where it has good bonding strength between slope and root itself. The tensile strength of 5, 10 and 15 primary and secondary root system of Vetiver grass exhibits larger than Bermuda grass. However, from the Scanning Electron
Microscope image the root of Vetiver grass cannot able function well as the moisture content reduces. In drought condition, the root of Vetiver grass might have a problem to act as root reinforcement toward the slope. While, in heavy raining season, the root of Bermuda grass cannot survive well since this grass planted on slope surface. The root system of Bermuda grass may break or fractures due to high absorbance of moisture content. It can be concluded that as the moisture content increases, the root matrix system of Vetiver grass has a good anchoring to the cut slope rather than Bermuda grass especially in heavy raining season in Malaysia tropical wet environment. The function of root matrix system of vegetation is mainly depending on moisture content and root morphology.

![Graph Tensile Strength versus Mean Moisture Content for Bermuda grass](image1)

**Figure 7.** The relationship between tensile strength and moisture content included SEM image for Bermuda grass.

![Graph Tensile Strength versus Mean Moisture Content (%) for Vetiver grass](image2)

**Figure 8.** The relationship between tensile strength and moisture content included SEM image for Vetiver grass
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