Mechanical Root Reinforcement of Bermuda Grass Toward Slope Stability

Noorasyikin,M.N, Zainab, M

Abstract: ***Bermuda grass is one of the bioengineering techniques which were widely applied for slope stabilization. In situ tests have been carried out on root of Bermuda grass at several locations by applied fabrication pull out test to determine the bonding strength between soil and root. The root samples and soil samples with and without roots then were brought to the laboratory to conduct tensile strength and shear box tests for further investigation. For insitu tests, it was found that the roots of Bermuda grass grow well with sandy soil compared to clay soil. In addition, the root of Bermuda grass also able to tolerate with dry weather. In term of tensile strength test, the root was found decreases as the root diameter decreases. Meanwhile, the root length was notified did not give any effect toward tensile strength. For shear strength test, the parameters which are cohesion and friction angle for soil with roots were found obtained higher values compared to soil only. The findings indicated that the Bermuda grass is a good choice of bioengineering technique for mitigation of slope failure in Malaysia tropical wet environment.***

Keywords: Root Matrix System, Pull Out Strength, Tensile Strength, Shear box, Slope stability

I. INTRODUCTION

Nowadays, slope hazards become one of the major global problem ([1],[2],[3],[5]-[7]) in geotechnical engineering nature of the topography and local weather condition. There are two common techniques which were widely applied for slope protection; mechanical technique and bioengineering technique. However, the engineer prefers used bioengineering technique due to its simple, low cost, does not require heavy machine and improve the shear strength of soil via root system. Under bioengineering technique, there are many types of seed of grasses which have been applied on soil slope such as Bermuda grass, Vetiver grass and Legume grass. Among of these grasses, the Bermuda grass is one of the most widely used in Malaysia due to low cost and faster growth.

II. BIOENGINEERING TECHNIQUE: BERMUDA GRASS

The scientific name for Bermuda grass is Cynodon dactylon. The family of Cynodon contains nine species which is the widest. The Bermuda grass can tolerate with soil pH scale of 5.5 to 8.0. It can stand for both conditions, either acid or alkaline soil. For nutrient needed, the most macronutrient require by this grass is Nitrogen where for good quality turf. Bermuda grass is more sensitive to cold temperature than in warm seasons. The root of this grass is fast growing and can survive with long absence of water. It spreads the seed through stolon and rhizomes at top and below level. Although at the top been killed, the grass can still stand with the presence of seeds in rhizomes. The Bermuda grass easily turns brown in color in dry weather but change to green color after heavy rainfall. [6] found that this grass can grow well with sandy soil and clay soil with low cost maintenance.

This study was carried out to investigate the suitability of soil type with Bermuda grass in Malaysia tropical wet environment. Besides that, the strength of soil with and without root also was examined to determine the bonding strength between soil and root system.

III. MATERIALS AND METHODS

A. In situ Pull Out test

The in-situ pull out apparatus was fabricated with specification shown in Figure 1. The specifications of the apparatus were designed with mechanical jack system, transducer, load rings and steel frame. The data measurement was conducted by rotated manually the mechanical jack system with time rate 0.2min/min. The data was recorded in Newton unit.

Figure 1: Fabrication of in situ pull out apparatus

B. Tensile Strength test

For tensile strength test, the test was carried out by using Shimadzu Universal Testing machine shown in Figure 2. A tensile strength of single root of Bermuda grass were measured with various diameter and length.

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The unit of tensile strength was recorded in Megapascal (MPa). The root length and diameter were recorded by using Venier Caliper and measured in unit millimeter (mm).

Figure 2: Root tensile strength test by Shimadzu Universal Testing machine

B. Direct Shear Box test

The Shear box test was conducted on soil with and without root system as shown in Figure 3. Based on the experiments, the main parameters of shear strength were determined such as cohesion and friction of angle by plotting a Mohr Coulomb graph.

Figure 3: Soil with roots in the square box

IV. RESULTS AND DISCUSSION

A. Determination of Force (In situ pull out test)

A graph of root pull out resistance of Bermuda grass with sandy soil (dry and wet weather – well grown and poorly grown) is shown in Figure 4 below. For well grown in dry weather, the root pull out resistance was acquired ranged values from 102.33 N to 229.8 N. While, for well grown in wet weather the root pull out resistance was attained decreases by 31% with range values from 73.88 N to 154.2 N. Meanwhile, for poorly grown in dry weather the root pull out resistance are ranged from 72.51 N to 99.9 N. For poorly grown in wet weather, the root pull out resistance was acquired decreasingly about 22% with range values from 52.3 N to 84.31 N. From the results obtained, it was found that the root pull out resistance for well grown consisted higher values compared to poorly grown by 40% with range values from 73.88 N to 229.8 N. While, the range values of root pull out resistance for poorly grown are between 52.3 N to 99.9 N.

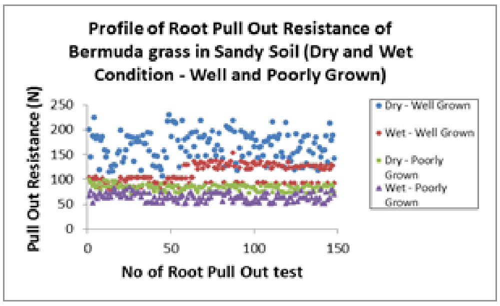

Figure 4: The Profile of Bermuda grass - Sandy Soil (Dry and Wet Weather – Well Grown and Poorly Grown)

A graph of root pull out resistance of Bermuda grass with clay soil (dry and wet weather –well grown and poorly grown) is shown in Figure 5. For well grown in dry weather, the root pull out resistance was found acquired range values from 49.86 N to 79.9 N. Meanwhile, for well grown in wet weather the root pull out resistance was found decreases by 38% which ranged from 30.75 N to 49.63 N. In dry weather, the root pull out resistance for poorly grown was obtained decreasingly about 69% which is ranged from 12.14 N to 29.63 N. Meanwhile, in wet weather the root pull out resistance for poorly grown are ranged from 13.24 N to 19.84 N. The forces required to pull out was found decreases approximately about 21%. Similar to root pull out toward sandy soil, the root pull out resistance for well grown was observed acquired higher values compared to poorly grown by 40% with range values from 12.14 N to 29.63 N.

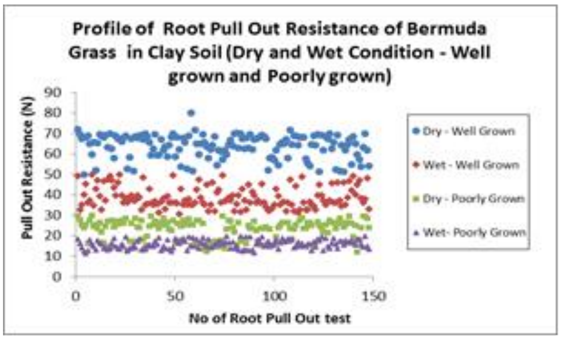

Figure 5: The Profile of Bermuda grass - Clay Soil (Dry and Wet Weather– Well Grown and Poorly Grown)

Based on the results obtained, it was observed that the root of Bermuda grass also capable to grow well with sandy soil compared to clay soil. Besides that, the roots were found able to survive in dry condition. [6] stated that this kind of grass able to grow although with long absence of water. So, these findings in this study had proven the statement. In term of hydrology mechanisms, the roots were observed did not anchor well to the soils either sandy soil or clay soil. The roots in wet weather were found easily to pull out and consisted lower force values compared in dry weather. This kind of grass normally planted on surface only for temporary purpose, so it can be said the root easily to break when in wet weather or after heavy raining season. In clay soil, the roots of Bermuda grass were found not so well bind the soil as the pull out resistance obtained was lower values compared with sandy soil. It can be summarized that the root of Bermuda grass able to act as root reinforcement toward sandy soil than with clay soil especially in dry weather.

B. Determination of Root Tensile Strength

A graph of single root tensile strength of Bermuda grass versus root diameter with sandy soil (dry and wet weather – well grown and poorly grown) is shown in Figure 6. In wet weather, the root tensile strength for well grown toward sandy soil was recorded ranged from 0.97 MPa to 243.42 MPa with root diameter 0.13 mm to 1.3 mm.

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In dry weather, the root tensile strength for well grown were recorded between 1.73 MPa to 165.77 MPa with root diameter 0.24 mm to 1.60 mm. For poorly grown in wet weather, the root tensile strength of poorly grown were obtained ranged from 0.47 MPa to 112.72 MPa with root diameter 0.28 mm to 1.32 mm. Meanwhile for poorly grown in dry weather, the root tensile strength were ranged between 0.73 MPa to 116.61 MPa with root diameter ranged from 0.33 mm to 1.35m. The trend of the graph presents curve where the tensile strength decreases as the root diameter increases.

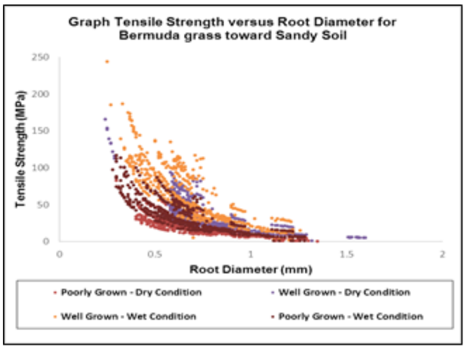

Figure 6: Relationship between Tensile Strength versus Root diameter for Bermuda grass with Sandy soil (Single Root)

A graph single root tensile strength of Bermuda grass versus root diameter with clay soil (dry and wet weather - well grown) is shown in Figure 7. The root tensile strength of Bermuda grass were found obtained lowest value toward clay soil compared to sandy soil. For well grown in wet weather, the root tensile strength was acquired ranged from 0.45 MPa to 159.10 MPa with root diameter 0.3 mm to 1.74 mm. While, for well grown in dry weather the root tensile strength was obtained ranged from 0.85 MPa to 140.11 MPa with root diameter 0.21 mm to 1.73mm. For poorly grown in wet weather, it was observed that the root tensile strength data were between 0.12 MPa to 104.36 MPa with root diameter 0.21 mm to 1.74 mm. While, for poorly grown in dry weather the root tensile strength was obtained between 0.28 MPa to 102.30 MPa where decreases about 32% with root diameter 0.13 mm to 1.72 mm. The graph shows similar pattern whereas the root tensile strength decreases with increases of root diameter.

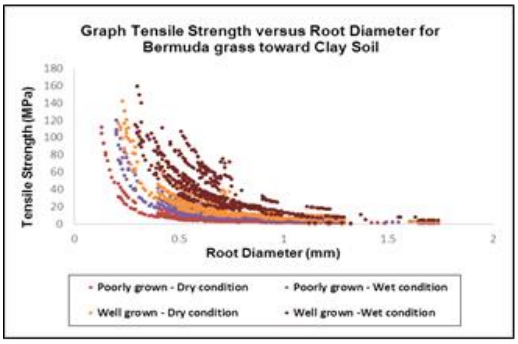

Figure 7: Relationship between Tensile Strength versus Root diameter for Bermuda grass with Clay soil (Single Root)

It can be summarized that the root of Bermuda grass capable to survive in sandy soil compared to clay soil for well grown and poorly grown (dry and wet weather). Besides that, the roots can stand with dry environment.

The equations of relationship between root tensile strength and root diameter with sandy soil and clay soil are shown in Figure 8. The power trendline was chosen to determine the best fitted R^2 relationship between root tensile strength and root diameter with sandy soil and clay soil. The relationship between root tensile strength and root diameter toward sandy soil and clay soil are as follows:

$$Y = 12.803x^{-2.098} \text{ with } R^2 = 0.5566 \text{ (with sandy soil)}$$
$$Y = 5.4994\,x^{-1.998} \text{ with } R^2 = 0.4737 \text{ (with clay soil)}$$

Where y is equal to root tensile strength (MPa) and x is representing root diameter (mm).

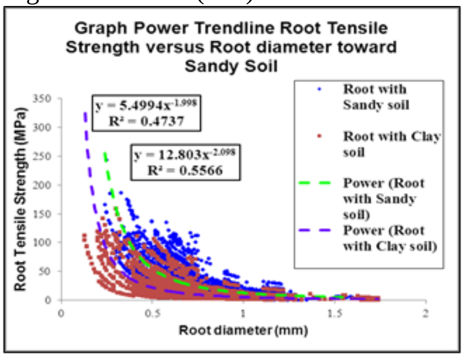

Figure 8: Graph Root Tensile Strength versus Root Diameter (Power Trendline) with sandy soil and clay soil

A profile of relationship between root tensile strength and root length for Bermuda grass with sandy soil is plotted as shown in Figure 9. For poorly grown in wet weather, it was found that the roots tensile strength with lowest and highest values of roots length, 40 mm and 206 mm are 49.8 MPa and 20.49 MPa respectively. While, the roots tensile strength with lowest and highest values of roots length, 40 mm and 230 mm are 98.37 MPa and 82.54 MPa for well grown in wet weather respectively. In dry weather, for well grown the roots tensile strength with lowest and highest values of roots length, 41 mm and 224 mm were found to be 65.3 MPa and 36.14 MPa respectively. While, for poorly grown in dry weather the roots tensile strength with lowest and highest values of roots length, 42 mm and 160 mm were found acquired 39.83 MPa and 11.56 MPa respectively.

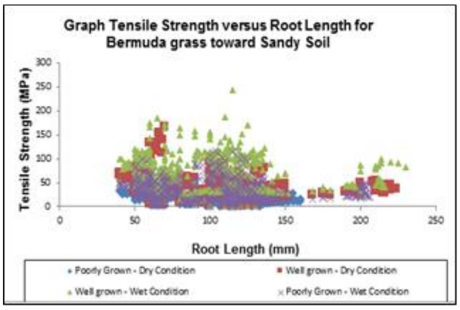

Figure 9: Relationship between Tensile Strength versus Root length for Bermuda grass with sandy soil (Single Root)

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A profile of relationship between root tensile strength and root length for Bermuda grass with clay soil is plotted as shown in Figure 10. For poorly grown in wet weather, it was found that the roots tensile strength with highest and lowest values of roots length, 40 mm and 168 mm are 19.05 MPa and 10.68 MPa respectively. While, for well grown in wet weather, the roots tensile strength with highest and lowest values of roots length 40 mm and 156 mm are 61.52 MPa and 25.31 MPa respectively. The roots tensile strength with lowest and highest roots length 40 mm and 175 mm for well grown in dry weather, were found to be 29.90 MPa and 13.07 MPa respectively. While, for poorly grown in dry weather the roots tensile strength with lowest and highest values of roots length 42 mm and 175 mm were found to be 30.71 MPa and 3.57 MPa respectively.

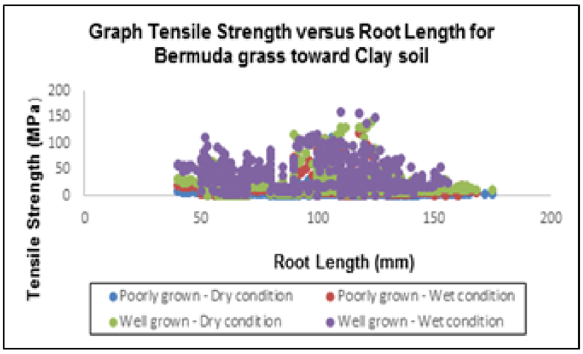

Figure 10: Relationship between Tensile Strength versus Root length for Bermuda grass with clay soil (Single Root)

All the graphs for all conditions with sandy soil and clay soil were observed have similar pattern where there is no any peak value recorded and there is no curve's trend. The values of roots tensile strength with root length were found also not reflected each other thus can be precised that the root length did not influence the bonding strength between root and soil. [4] also found similar finding where there is no any relationship between root tensile strength and root length.

C. Determination of Shear Strength with and without root of Bermuda grass

Figure 11 shows the shear strength parameters of soil with root at Lanchang area. The data of shear stress gradually increases and decreases after reached at peak value. It can be observed that the values of cohesion and friction angle obtained higher values for soil with root compared to soil without root. The friction angles of soil were found lower than soil with root where it presents that the root gives effect toward strength of soil. The summaries of findings for shear strength of soil with and without root of Bermuda grass are shown in Table 1. It tabulated that the soil with root of Bermuda grass attained higher bonding strength compared to soil only. At Lanchang area, the soil with root of Bermuda grass acquired cohesion and friction angle about 42 kN/m^2 and 84.34^0 respectively. The cohesion and friction of soil with root at Temerloh WB were found to be 36 kN/m^2 and 84.3^0. Meanwhile, the cohesion and friction angle at Temerloh EB area were found to be 42 kN/m^2 and 84.34^0 respectively. The cohesions and friction angles of soil without root for each place were found decreases approximately about 29% and 2% respectively. It can be summarized that the root of Bermuda grass presents important role as root reinforcement where it binds the soil together.

Table 1: Shear strength parameters of soil with and without root of Bermuda grass

Locations	Cohesion (c)	Angle (θ)	Normal Stress (kPa)
Lanchang (Soil only)	30	82.7	8.175
			16.35
			24.53
Lanchang (Soil + root)	42	84.34	8.175
			16.35
			24.53
WestBound Temerloh (Soil only)	22	82.7	8.175
			16.35
			24.53
WestBound Temerloh (Soil + root)	36	84.3	8.175
			16.35
			24.53
EastBound Temerloh (Soil only)	39	82	8.175
			16.35
			24.53
EastBound Temerloh (Soil + root)	49	84	8.175
			16.35
			24.53

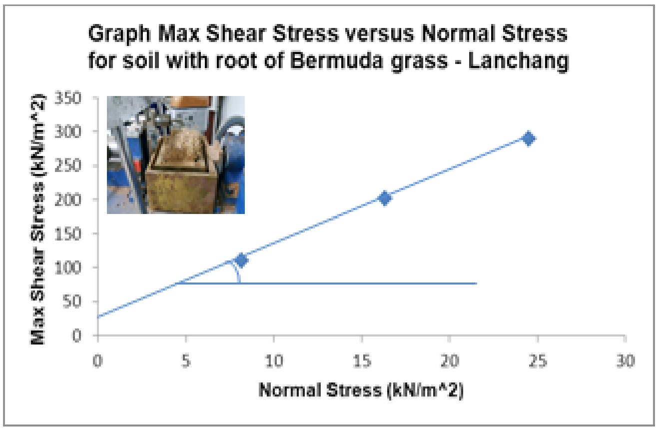

Figure 11: Graph maximum shear stress versus normal stress for soil with root in Lanchang area

V. CONCLUSION

The roots of Bemuda grass can survive with sandy soil than clay soil. Besides that, this kind of grass can grow well in drought condition. In term of root properties, the root tensile strengths were found decreases as the root diameter increases. While, root lengths were found did not give any effect toward root tensile strength. It can be concluded that the root of Bermuda grass is a good choice for mitigation slope failure where it acts as root reinforcement toward the soil especially with sandy soil. The findings of shear strength show that the cohesion and friction angle obtained higher values with presence of roots.

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The output from the results provide growth behavior of Bermuda grass in Malaysia and can be a benchmark to develop a root reinforcement of vegetated soil.

VI. ACKNOWLEDGEMENT

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REFERENCES

1. Bibalani,G.H.,& Majnounian,B. (2008). The Role of Forest and Nonforest Species on Slope Stability in the North of Iran. *J.Agric.Sci.Technol.[2008]Vol.10*:371- 381.
2. Bujang,.B.K.H & Sina, K. (2010). Study of Root Theories in Green Tropical Slope Stability. *Electrical Journal of Geotechnical Engineering. Vol.15 [2012]*, Bund Q.
3. Egeli,I & Firat,H. (2011). Mechanism and Modeling of shallow soil slopes stability during high intensity and short duration. *Journal Scientia Iranica.* Vol.18,Issue 6,page 1179-1187
4. Faisal,A (2010). Use of vegetation for slope protection :Root mechanical properties of some tropical plants. *International Journal of Physical Sciences*. Vol.5(5). pp 496-506
5. Nomessi,K., Thierr.F., Kouami.K., Kouma,N., & Lac,P. (2006). Disaster Mitigation of Debris Flows, Slope Failures and Landslides. Universal Academy Press Inc Tokyo Japan,pp 561-56
6. Raj,B (2009). Bermuda attractions. Forum network
7. Sasan,M., Bujang, B.K.H., & Vahed, G. (2009). Evaluation on Root Theories and Root Strength Properties in Slope Stability. *European Journal of Scientific Research.Vol.30 No.4*.594-60