Investigation on the Shear Strength of a Soil with Mura Grass Roots

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Abstract: This study investigates the effect of Mura grass (*Vetiveria Nemoralis*) roots on the shear strength of soil, which is essential for reducing soil erosionâ€"a significant concern in geotechnical engineering. The stability of civil engineering structures relies heavily on geotechnical stability. Vegetation plays an important role in enhancing the strength and stability of soil by interlocking soil particles and improving water infiltration, thereby reducing the potential for erosion. The study involved gathering Mura grass samples from Calauan, Laguna, Philippines, and conducting direct shear tests in accordance with ASTM D3080 standards to evaluate the soil reinforcement impact of Mura grass roots. The experiment consisted of conducting numerous trials with varying loads in order to assess the interaction between soil and plant roots in a controlled environment. The base soil served as the control group for result comparison. The findings indicate that the roots of Mura grass have a notable impact on enhancing the shear strength of soil. This suggests that there are potential advantages for using Mura grass in stabilizing soil in areas susceptible to erosion. Roots not only improve the internal cohesion of the soil, but also enhance its resistance to shear forces, offering a natural and sustainable approach to strengthen soil and prevent erosion.

Key Words: mura grass; soil; geotechnical engineering; shear; direct shear;

1. INTRODUCTION

Soil erosion is a significant issue in geotechnical engineering that has a direct impact on the stability and safety of civil engineering projects (Ganesan et al, 2024). The stability of foundations for structures such as buildings, bridges, and infrastructure is a major concern. Soil erosion can lead to settlement, tilting, or structural failure of the foundations. Geotechnical engineers have a vital role in evaluating the potential for erosion during the design stage and may need to take preventive measures against erosion near critical structures (Fatehi et al, 2021).

Additionally, ensuring the stability of both natural and engineered slopes is of utmost importance. Landslides, which are significant hazards to infrastructure and public safety, can occur when slopes fail due to erosion (Wu et al, 2022). Geotechnical engineers have the responsibility with performing rigorous analyses, research, and, if needed, intervention (Phoon, 2023).

Another vital component of geotechnical engineering involves the design and construction of erosion control structures (Hartman et al, 2016). The purpose of these structures, such as retaining walls, gabion baskets, and erosion control blankets, is to stabilize slopes and minimize the risks of soil erosion. When erosion occurs frequently, geotechnical engineers may suggest soil stabilization techniques to alter soil properties and enhance its resistance to erosion (Ramesh, 2021).

Prior to commencing any construction activities, geotechnical engineers perform thorough site assessments to evaluate soil conditions, which include the potential for erosion. This important information enables the design of appropriate foundation systems and erosion control measures customized to the particular project site. The presence of vegetation plays a crucial role in preventing soil erosion (Löbmann. 2020). The significance of this lies in its various contributions to erosion control. Initially, the roots of plants fortify the soil by interlocking soil particles, thereby augmenting its stability. This reinforcement emulates a natural support system that mitigates erosion caused by water and wind. Additionally, vegetation enhances soil structure by augmenting porosity and facilitating water infiltration, thereby reducing surface runoff and mitigating the erosive impact of rainfall (Niyomukiza et al, 2023). In addition, vegetation serves as a defensive barrier, safeguarding the soil from the direct force of raindrops and flowing water, thereby reducing soil detachment and surface erosion. Additionally, it slows the velocity of water, thereby reducing its ability in carrying soil particles away. Vegetation has the ability to capture sediment particles from runoff water, thereby maintaining the quality of water in nearby water bodies. As plants develop and their root systems strengthen, they offer durable erosion control as they mature and their root systems become more robust. The objective of this study is to evaluate the shear strength of soil when subjected to the presence of Mura grass.

2. METHODOLOGY

2.1 Plant Specimen

Specimens of *Vetiveria Nemoralis*, commonly known as Mura Grass, were gathered from Calauan, Laguna, Philippines, as depicted in Figure 1. Plants are one-month-old, which served as a representation of the initial stages of plant growth. The soil samples were meticulously transferred to containers while preserving their root systems.

2.2 Direct Shear Test

The direct shear test adhered to the prescribed protocol outlined in ASTM D3080. Each sample plant species underwent three (3) repetitions of the direct shear test for each load.

The base soil from the study site was used as the control group to assess the impact of the plants on the soil. A segment of the plant roots, together with the soil samples, were placed into a 60x60x40mm mold and tested using a direct shear apparatus. In addition, soil samples taken from the same depth but excluding any root portions were subjected to testing. The table provides the quantity of soil required for conducting the direct shear strength test, along with the number of trials conducted for each test.

Fig. 1. Mura Grass farm

Table 1. Quantity of Soil for Testing

Description	Soil Amount per Trial (g)	Number of Trials
Base Soil	195	3
Soil with Mura Grass	190	8

The experiment required the preparation of samples in a shear box before conducting the tests. The direct shear test procedures were conducted based on the type of soil collected, which was determined to be fine-grained soil. The first stage of the test entailed the preparation of the soil sample. A soil sample that accurately replicated the conditions of the project site was necessary, with a moisture content of 17.27% that corresponded to the specific area being investigated. The soil specimen was meticulously irrigated to attain the targeted moisture level, and subsequently it was shaped and sized accordingly to fit the shear box. Strictly adhering to the specifications was essential in order to maintain consistency in sample dimensions.

The initial soil condition entailed reconstituting the soil into the shear box without any supplementary components. The sample preparation for the shear box test was modified according to the soil condition, which encompassed the base soil, soil with vertically oriented roots. The shear box was arranged in accordance with Figure 2 for conducting tests on soil with vertical roots.

For the vertical roots condition, the plant roots were placed vertically into the shear box, and soil was added cautiously to avoid compressing the roots of the sample. By implementing these conditions, it was feasible to assess the impact of root systems on the shear strength parameters of the soil.

The experimentation employed plain grid plates to replicate an undrained condition for all tests. After completing the necessary sample preparation, the direct shear strength test was started.

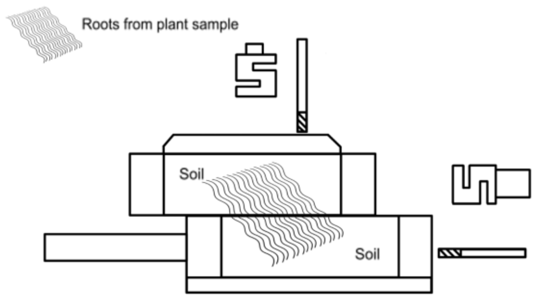

Figure 2. Diagram of the Shearing Specimen

The test procedure entailed placing the loading block onto the apparatus, subsequently followed by the shear box. Three different normal loadings (90 kPa, 45 kPa, 22.5 kPa) were applied to the loading cell for each of the various soil conditions. The selection of applied normal stresses was contingent upon the expected loads in the design provided by DPWH, taking into account a soil unit weight of 15 kN/m^3 and an embankment height of 6 meters. In order to determine the precise weight needed to apply the desired normal stress, the ideal weight was multiplied by the area of the sample, which measured 60 cm x 60 cm. As a result, the specimens were subjected to applied loads of 3.30 kg, 1.65 kg, and 0.83 kg, respectively.

Transducers were meticulously affixed during the direct shear test to precisely gauge displacement during the entirety of the shearing procedure. The test was conducted until a stroke limit of 15 mm was achieved, at which point the apparatus readings were carefully documented. In order to achieve thorough data collection, the experiment was replicated by obtaining more soil samples and subjecting them to different loads and conditions. This included conducting one set of three loadings on the base soil, three sets of three loadings on the horizontal root, and two sets of three loadings on the vertical roots. Additionally, an extra set was performed with two loadings at 90 and 45 kPa. A total of 18 samples underwent testing as part of the direct shear experiments.

The D3080 Direct Shear Test is a widely employed laboratory test that ascertains the shear strength characteristics of soils. This test yielded crucial data for the design and analysis of geotechnical engineering. The subsequent paragraphs delineate the sequential process for carrying out the D3080 Direct Shear Test.

After the sample was prepared, its initial weight, also known as the wet soil weight, was measured and recorded using a weighing scale. This measurement served as a point of reference for the subsequent calculations and comparisons. Ensuring that the moisture content remains within the desired range is essential for obtaining precise test results.

Subsequently, the direct shear apparatus was prepared for the test. The apparatus was comprised of two distinct sections: the upper and lower halves. The lower portion was stabilized, while the upper portion had the potential to be horizontally displaced in relation to the lower portion. The sample was positioned meticulously between these two halves, with meticulous attention given to ensure accurate alignment and perfect centering.

After the normal loadings were prepared, the test began by applying a constant rate of 0.8 mm/min to load the upper half of the apparatus until the strain limit was reached. The upper half was subjected to a desired normal loading, and its horizontal displacement was incrementally increased at a controlled rate. The displacement resulted in the soil sample experiencing shear deformation along the predetermined plane of failure. The loading machine recorded the applied load during the shear process.

It was crucial to closely observe the shear behavior of the soil sample during the test. Observations were conducted to assess any alterations in sample characteristics including the presence of peak shear strength, residual shear strength, and any failure modes.

After the shear test was finished, the final measurements and observations were documented.

This encompassed the mass of the soil sample prior to and subsequent to desiccation in an oven. The measurements were essential for determining shear strength parameters, including shear stress and shear displacement.

3. RESULTS AND DISCUSSION

3.1 Base Soil

Figure 3 illustrates the correlation between shear stress and shear strain observed in the direct shear test of the base soil. The graph displayed the soil's behavior under different loadings by plotting the data points. A uniform trend was consistently observed across all loadings in the early portion of the curve. The shear stress exhibited an initial rise and eventually reached a maximum value, which corresponded to the yield strength of the soil. At the point of yield strength, the soil underwent substantial deformation, shifting from its elastic properties to its plastic properties.

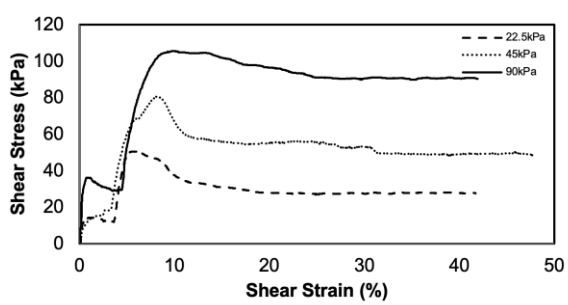

Fig. 3. Shear Strain vs. Shear Stress of Base Soil

After reaching the yield strength, the curve showed a slight decline. This phenomenon can be ascribed to the soil's capacity to redistribute stress and adapt to the applied load. Following that, the curve exhibited an upward trajectory and reached its highest point, attaining the maximum soil strength of 50.30, 80.54, and 105.41 kPa under the respective normal pressures of 22.5, 45, and 90 kPa, as depicted in Figure 3. Figure 4 illustrates the correlation between peak stress and normal stress of the base soil. The base soil has an internal friction angle of 37.42° and a cohesion of 37.89 kPa, which are the interface friction parameters for the base soil.

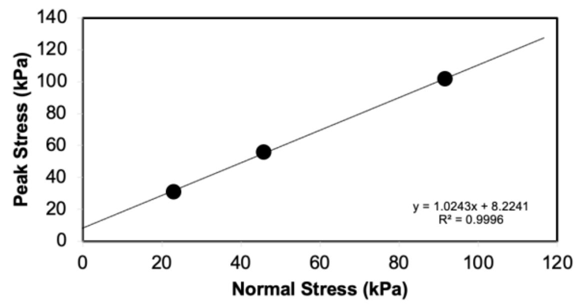

Fig. 4. Relationship between Peak Stress and Normal Stress (Base Soil)

3.1 Soil with Mura Grass Roots

The relationship between shear stress and shear strain of the soil with vertical roots was illustrated in Figure 5. The soil's ultimate strength was measured as 43.24, 62.74, and 135.65 kPa under normal pressures of 22.5, 45, and 90 kPa, respectively, as depicted in the figure.

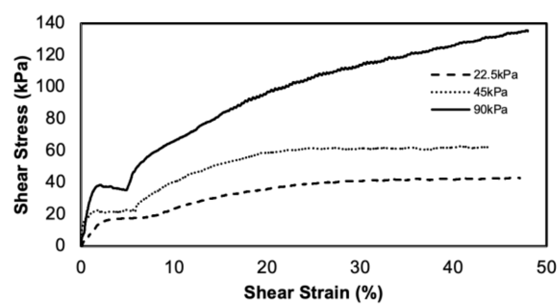

Fig. 5. Shear Strain vs. Shear Stress of Soil with Mura Grass Roots

Figure 6 illustrates the correlation between the maximum stress and the regular stress of the soil containing vertical roots. The sample yielded an internal friction angle of 54.08° and a cohesion value of 6.82 kPa. These values represent the interface friction parameters between the soil and the vertical roots.

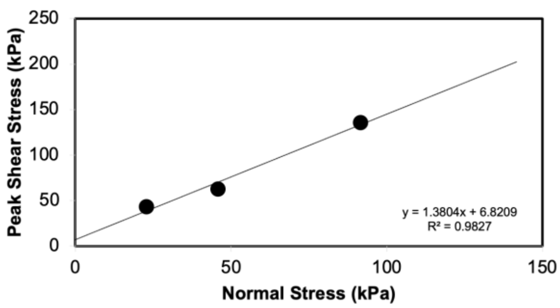

Fig. 6. Relationship between Peak Stress and Normal Stress (Soil with Mura Grass Roots)

The research conducted by Badhon et al. (2019) demonstrated that the correlation between shear stress and shear strain in vetiver rooted sand samples. The soil's ultimate strength was measured as 20.93, 23.74, and 35.91 kPa under normal pressures of 10.84, 15.49, and 30.98 kPa, respectively. Based on the shear test result, it was noted that the variation in shear strength of the soil with roots was not uniform.

Furthermore, Badhon (2019) presented the correlation between the maximum stress and the normal stress of the soil in the presence of vertical roots. The sample yielded an internal friction angle of 37.03° and a cohesion value of 10.46 kPa. These parameters represent the interface friction between the soil and the vertical roots. When comparing the experimental results with the findings of Badhon (2019), it was observed that despite the variations in parameters, the general behavioral patterns in both studies exhibited similarities.

As roots grow and spread throughout the soil, they intertwine with soil particles, creating an intricate network of fibers that efficiently combine the soil. This interconnected system functions as a support, greatly improving the cohesiveness of the soil structure. As a result, the soil develops greater resistance to shear forces, such as erosion.

4. CONCLUSIONS

The study conducted a comprehensive analysis of the effect of Mura grass roots on the shear strength of soil, emphasizing its significant ability to improve soil stability and reduce erosion. The direct shear tests conducted in accordance with ASTM D3080 standards demonstrated a significant enhancement in the shear strength of soils when integrated with Mura grass roots, as compared to the control samples of base soil.

Subsequent analysis has demonstrated that the existence of Mura grass roots not only enhances the soil's resistance to sliding but also its internal bonding. This improvement is credited to the complex system of roots that intertwine with soil particles, resulting in a more unified and stable soil structure. Biotechnical stabilization techniques are being increasingly acknowledged for their ability to provide both environmental sustainability and engineering efficacy.

Although the advantages of Mura grass are evident, additional investigation is required to enhance its utilization in various soil types and environmental circumstances. Future research should prioritize conducting comprehensive, extended evaluations of the performance of Mura grass in different climatic conditions, as well as investigating its interactions with other plant species and engineering materials. Moreover, implementing these vegetative techniques on a larger scale in real-world engineering projects would yield more extensive data and practical insights regarding their feasibility and performance metrics.

5. ACKNOWLEDGMENTS

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