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STUDY OF ROOT-REINFORCEMENT EFFECT ON SHEAR STRENGTH PARAMETERS OF SOIL OBTAINED BY DIRECT SHEAR TESTS

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ABSTRACT

The use of vetiver for protecting earth slopes is gaining increased recognition due to its massive root network. In an attempt to evaluate the effect of root-reinforcement on shear strength of rooted soil, laboratory tests have been conducted on vetiver rooted soil in an undisturbed condition. Both cohesive and cohesionless soils have been considered. Vetiver grasses were planted in 300 mm dia PVC pipe containing both clayey and sandy soils. Undisturbed rooted soil samples were prepared from the planted pipes after 180 days of the plantation. Direct shear tests were conducted in Consolidated Undrained condition under normal stresses varying from 10 kPa to 35kPa with moisture content around 19%. From test results, it has been observed that, angle of internal friction has increased compared to that of bare soil but cohesion decreases for the case of both clayey and sandy soil samples. This may occur because vegetation root mainly increases the shear strength by transferring shear stresses into tensile resistance in fiber inclusion. In laboratory test samples, the boundary conditions that usually exist in field samples cannot be achieved. Roots are not sufficiently long and constrained at their ends in laboratory shear tests. So when the shear force comes, the bond between root and clay soil particles fail and in case of sandy soil, friction between root and sand particles cannot contribute to shear strength. Larger specimen with improved boundary conditions is required for evaluating the effect of rooted shear strength.

Introduction

The use of vegetation for slope stabilization started in ancient times. In more recent times, the role of vegetation in some specific geotechnical processes has been recognized. Vegetation may affect slope stability in many ways. Comprehensive reviews may be found in (Islam et al., 2017), (Islam and Badhon, 2017), (Mickovski and van Beek, 2009), (Coppin and Richards, 1990). The stability of slopes is governed by the load, which is the driving force that causes failure, and the resistance, which is the strength of the soil-root system. The weight of plants growing on a slope adds to the load whilst the roots of plants serve as soil reinforcements and increase the resistance. In addition, vegetation also influences slope stability indirectly through its effect on the soil moisture regime. Vegetation increases the shear strength of the soil, thus increases the resistance.

To evaluate the actual performance of vegetation for protection of embankments, it is necessary to estimate the factor of safety against the natural forces. Vegetation most prominently enhances the stability of earthen slopes by root reinforcement (Islam and Shahin, 2013). Different tests were conducted by different researchers (e.g., Verhagen et al., 2008, Islam et al., 2010) to know the strength of vegetation roots for the analysis of the stability of slopes. Islam et al. (2013) conducted the in-situ test and also conducted a direct shear test on laboratory reconstitute soil samples at different root content to know the shear strength of vetiver grass. But Parshi (2015) found that shear strength properties of rooted soil obtained from the laboratory tests on reconstituted samples and in-situ tests are significantly different. This paper aims to present an investigation program of the vetiver root-reinforcement system for slope stabilization using undisturbed samples obtained from PVC pipe.

Methodology

Vetiver grass was planted in 75 mm dia PVC pipe, containing both sandy soil and clayey soil. Sandy soil sample was collected from Buriganga river bed and clayey soil sample was collected from Buriganga river bank.

A series of laboratory tests were conducted to determine the index properties of these soil samples according to ASTM standard test procedure. Undisturbed rooted soil specimen of 62.5 mm diameter was retrieved from pipes after 180 days of plantation. Direct shear tests were conducted on undisturbed samples to determine the shear strength of the soil-root matrix.

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Preparation of sand samples

Grease layer was given at the inner side of the pipe so that soil can be extruded easily during testing. Cement (5% of dry weight of sand) was mixed with sand so that sand soil sample does not collapse during testing. 20% water was added to the sand cement mixture. This moist soil sample was poured in 75mm dia and 300mm long PVC pipe. Soil was compacted in three layers having approximately 100mm equal layer thickness. Each layer was compacted by 300mm long steel tamping rod. 25 blows were given in each layer. Vetiver was planted in 8 soil samples, prepared in PVC pipe 20 April, 2016 and 4 samples were kept bare.

Preparation of clay samples

Clay sample was collected from Buriganga river bank. Undisturbed sample from Buriganga river bank has been collected in 75mm dia PVC pipe. Then vetiver clump was planted in the pipes on 30 April, 2016.

Plantation in PVC pipes and collection of undisturbed sample

Vetiver grass has been planted in 75 mm dia PVC pipe (Figure 1), containing sandy soil (collected from Buriganga river bed) with 5% cement and clayey soil (collected from Buriganga river bank). Plantation was done by the early monsoon. Undisturbed samples of rooted soil were retrieved from thus planted pipes after 180 days. Figure 2 demonstrates the procedure of retrieving undisturbed rooted soil specimen of 63.5 mm diameter for direct shear tests. Samples were collected 75 mm below from the top surface as shown in the Figure 1(c) to avoid the disturbance and nonuniformity of top layer soil. In the laboratory, direct shear tests were conducted to determine the shear strength parameters of undisturbed rooted soil and bare soil collected from pipes. The soil sample was placed carefully in the shear box from the ring. Then the desired normal load was applied.

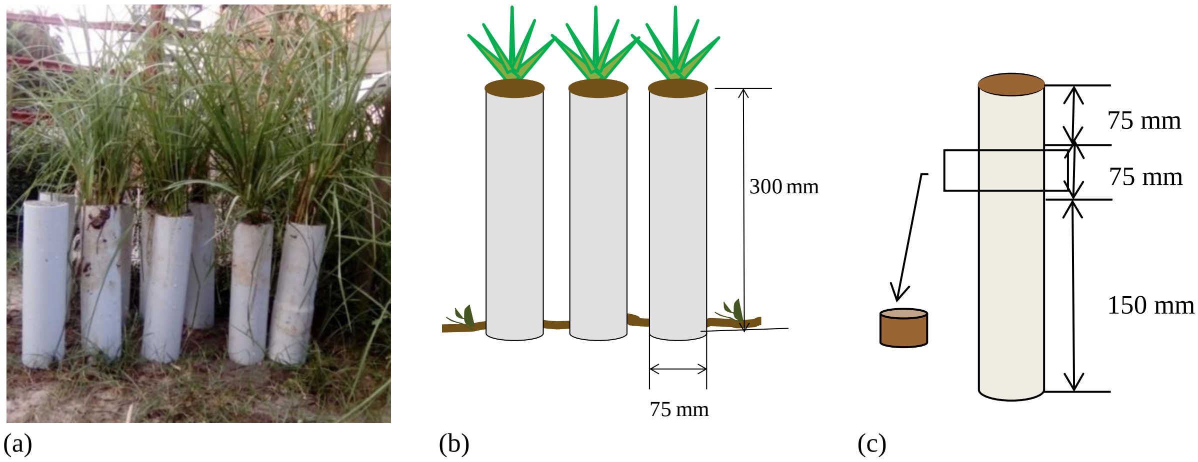


Figure 1. Vetiver plantation scheme (a) Vetiver grass planted in PVC pipe; (b) Schematic diagram of vetiver plantation in PVC pipe; (c) Schematic diagram of retrieving undisturbed sample from PVC pipe

Figure 2. Steps of sample preparation (a) Soil retrieved from pipe, (b) Collection of 62.5 mm dia specimen from 75 dia soil sample, (c) Specimen in probing ring

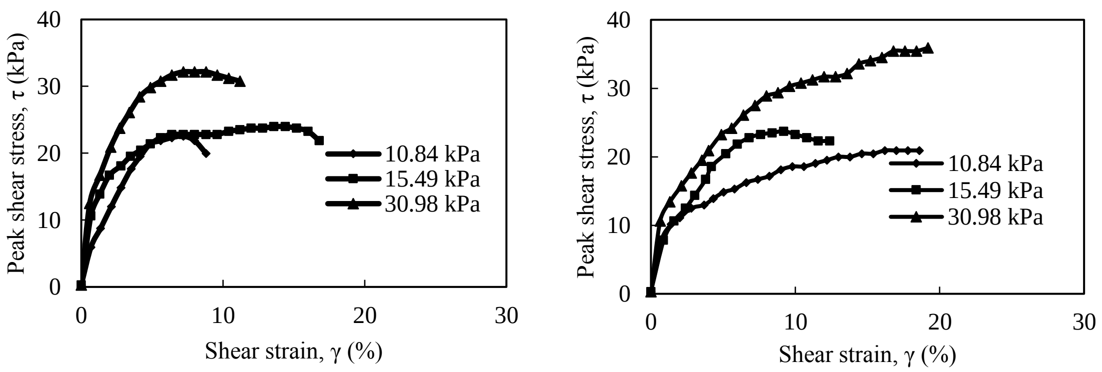
Vertical displacement dial gauge was attached to record the vertical deformation with respect to time. Enough time was allowed for consolidation before applying the shear force. When two consecutive vertical deformation dial readings were same, the shear force was applied to the soil sample with a constant strain rate of 0.75 to 1.25 mm/min. The lateral deformation was recorded by a lateral constant strain rate of 0.75 to 1.25 mm/min. The lateral deformation was recorded by a lateral displacement dial gauge of 25 mm capacity. The applied shear force was recorded by a load dial gauge of 2.22 kN capacity.

Results and Discussions

Direct shear tests were conducted on undisturbed clayey and sandy sample collected from PVC pipes. The cement mixed with sand was Basundhara Portland Composite Cement. Specific gravity of the sandy soil was 2.74 and clayey soil was 2.55. The sand was poorly graded having coefficient of uniformity c_u=1.86 and coefficient of curvature c_c=1.1. The clayey soil sample collected from Buriganga river bank was Clay of low plasticity or Lean clay. Clay, silt and sand content of the soil sample were respectively 11%, 79%, 10%. The liquid limit was 42%, plastic limit was 23% and plasticity index was 19%. Three bare soil specimens and three rooted soil specimens were tested for both sandy soil and clayey soil under three different normal loads. The selected normal loads were 10.84 kPa, 15.49 kPa and 30.98 kPa.

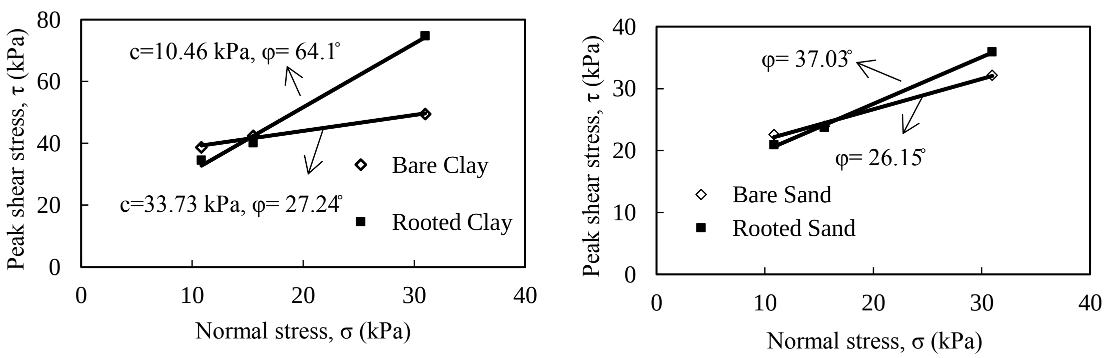
Table 1. Comparison of peak shear strength and shear strain of undisturbed bare and rooted soil

Sample type	σ_n (kPa)	Bare sample		Rooted sample		$\Delta\tau_{max}$	$\Delta\gamma$
		τ_{max} (kPa)	γ (kPa)	τ_{max} (kPa)	γ (kPa)		
Clay	10.84	38.72	2.4	34.51	6.4	-4.21	4
	15.49	42.47	4.2	40.13	0.96	-2.34	-3.24
	30.98	49.5	5.4	74.79	5.24	25.29	-0.16
Sand	10.84	22.57	7.2	20.93	15.4	-1.64	8.2
	15.49	23.91	14.4	23.74	9.2	-0.17	-5.2
	30.98	32.17	8.8	35.91	15.2	3.74	6.4



(a) (b)

Figure 3. Stress vs strain curves for (a) Bare sand sample (b) rooted sand sample



(a) (b)

Figure 4. Shear stress vs normal stress curves for undisturbed (a) clay sample, (b) sand sample

Figure 3 shows the shear stress vs shear strain curves for these normal loads. Water content was 21% for bare and rooted clayey samples and 19% for bare and rooted sandy samples. The direct shear test results have been shown in table 1. From Figure 4, it has been seen that for both clayey and sandy samples, angle of internal friction of rooted sample is higher than that of bare soil but cohesion of rooted sample is lower than that of bare soil for both cases.

From shear test result, it has been observed that the change of shear strength of rooted soil in comparison to bare soil is not consistent. Root fibers increase the shear strength of soil primarily by transferring shear stresses that develop in the soil matrix into tensile resistance in the fiber inclusions via interface friction along the length of imbedded fibers.

The mobilized tensile stress of root fibers depends upon the amount of fiber elongation and fixity of the fibers in the soil matrix. Full mobilization can occur only if the fibers elongate sufficiently and if the imbedded root fibers are prevented from slipping or pulling out. The latter requires that the fibers be sufficiently long and frictional, constrained at their ends and/or subjected to high enough confining stresses to increase interface friction. These may lack in laboratory shear test samples. In case of clay samples when the shear force come, the bond between root and soil particles fails. For sand samples, friction between soil particles and root cannot contribute. So, the effect of root content on shear strength of rooted soil cannot be evaluated through laboratory shear tests.

Conclusions

It has been found that addition of root has influence on shear strength of soil. Due to inclusion of root, shear strength increased up to 51.1%. But in some cases, shear strength decreased for rooted soil in comparing to bare soil. However, no particular relation could be developed from these laboratory test results. Larger specimen with improved boundary conditions is required for evaluating the effect of rooted shear strength.

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