Geotechnical Behavior of Fine Grained Soils Mixed with Randomly Oriented Plant Roots

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ABSTRACT A number of studies have been conducted recently to investigate the influence of randomly oriented fibers on the geotechnical behavior of coarse grained and fine grained soils. The presence of plant roots is a natural means of incorporating randomly oriented fiber inclusions in the soils. An experimental study was carried out to investigate the influence of randomly oriented plant roots on the geotechnical behavior of two fine grained soils, namely silty clay and clayey silt. Plant root, namely Japanese Dappled Willow, with varying percentages of 0% to 2% was used in the experiments. The plant root inclusions increased the strength of the soil specimens.

INTRODUCTION

Geotechnical properties of soils are affected considerably with the presence of foreign components, and randomly oriented roots are one of them. Roots in soils acts as reinforcing material, which in turn increase the shear strength of the soil and thus benefits the stability of slopes (Gray & Sotir, 1996). Plant roots in soil also dominantly decrease the inter-rill and rill erosion (Gyssels et al. 2005). Plantation on the natural slopes is also one of the methods in ecotechnology that help achieve the most economic and pro-environmental solution for attaining stable slopes (Norris et al. 2008). Mickovski et al. (2009) conducted experimental studies on mechanical properties of the agricultural soil (sand as major constituent) planted with different diameters of roots. The studies showed that the shear strength of the soil considerably depends on the root diameter; the higher the diameter, the greater the shear strength. However, studies did not present more information about the random distribution of roots in the soil and its effect on geotechnical properties. Overall, studies documented are limited to the coarse grained soils. The main objective of this paper is to study the effect of randomly oriented plant roots on the geotechnical properties of fine grained soils. Based on the experimental results, the stability analysis of an infinite slope with respect to different percentages of root mass is also evaluated in this paper.

MATERIALS AND METHODOLOGY

Two different soil types, namely silty clay and clayey silt, were used in all experiments. The plant root Japanese Dappled Willow was used as reinforcement. The grain size distribution curves of two soils are shown in Fig.1. The physical properties of soils used in this study are given in Table 1. Specimens were then prepared with different percentages of plant roots at maximum dry density (MDD) and optimum moisture content (OMC) values corresponding to the initial soil sample. Unconfined compression (UC) tests were conducted on these specimens to find the stress strain behavior. To find the effect of dry and wet compaction on the root reinforced samples, UC tests were also conducted on the 2% plant root with soil sample compacted on dry and wet of OMC. The undrained shear strength (USS) is equal to 0.5 times UC strength.

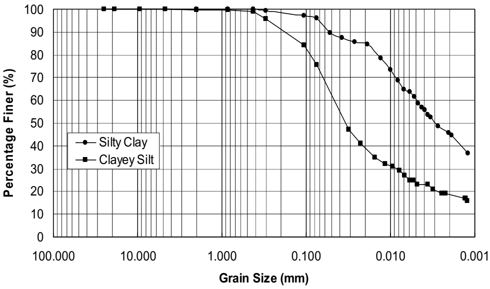

Fig.1 Grain Size Distribution Curves for Two Soils.

TABLE 1. Properties of Soils

Property	Test Method	Silty Clay	Clayey Silt
Organic Content (%)	ASTM D2974	5.05	5.4
Specific Gravity	ASTM D854	2.68	2.60
Gravel (%)	ASTM D422	0.0	0.0
Sand (%)		3.8	24.6
Silt (%)		38.2	51.4
Clay (%)		58.0	24.0
Liquid Limit (%)	ASTM D4318	32.8	26.0
Plastic Limit (%)		16.3	22.0
Plasticity Index (%)		16.5	4.0
Optimum Moisture Content (%)	Harvard Miniature Compaction	18.0	20.0
Maximum Dry Density (g/cm^3)		1.78	1.6

RESULTS AND DISCUSSION

Stress-Strain and Undrained Shear Strength with Varying Root Mass

The stress strain responses of silty clay and clayey silt, with varying percentages of root masses, are shown in Fig.2(a) and Fig.2(b), respectively. As the percentage of root mass increases from 0% to 2%, the UC strength also increases. The stress strain response of clayey silt shows the failure to be brittle in nature with a root mass of up to 1.5%, and ductile in nature when the root mass is increased to 2%.

Addition of root mass on two soils resulted in an increase in the USS (Fig. 2(c)). The increase in strength of silty clay with percent root mass was large in comparison to clayey silt.

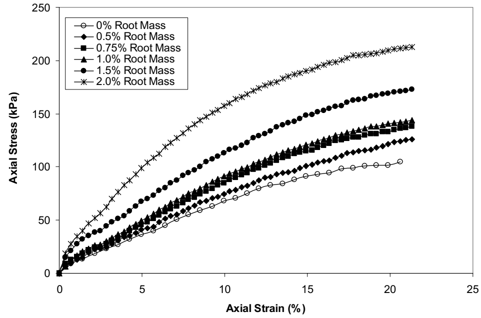

Fig. 2(a) Stress Strain Response for Silty Clay.

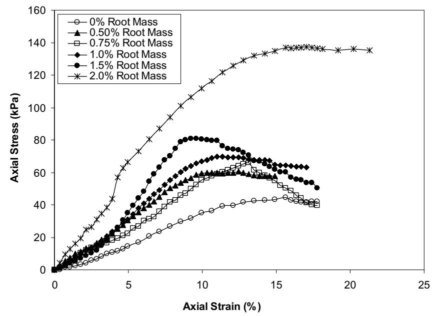

Fig. 2(b) Stress Strain Response for Clayey Silt.

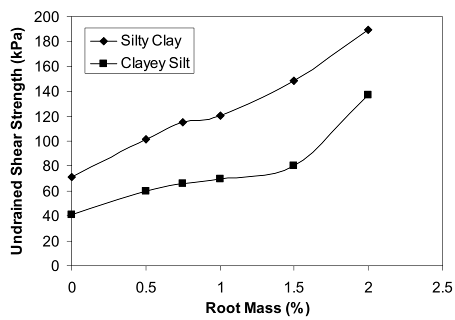

Fig. 2(c) USS of Silty Clay and Clayey Silt.

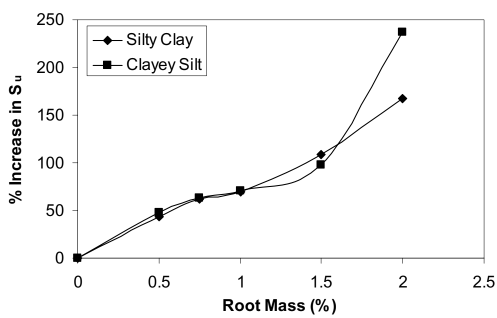

Fig. 2(d) Percentage Increase in Shear Strength.

Figure 2(d) shows the percentage increase in shear strength with respect to percentage root mass added. When the root mass was increased from 1.5 to 2% a drastic increase in USS in the case of clayey silt was observed (from 100 to 240%).

Effect of Compaction on Shear Strength for 2% Root Mass

The OMC and MDD of silty clay and clayey silt with 2% root mass changed slightly when compared to the values without root mass (Fig. 3). The dry density of silty clay is higher than the dry density of clayey silt in both cases: without root mass and with 2% root mass.

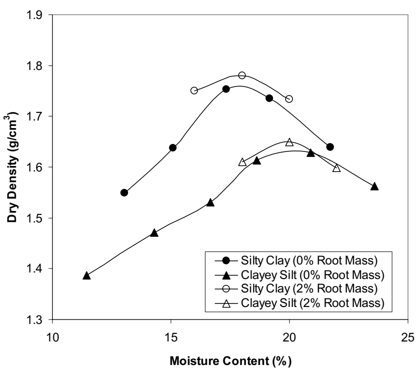

Fig. 3 Effect of Compaction for 2% Root Mass.

The effect of compaction on the stress strain response at different moisture contents on dry of OMC and wet of OMC for silty clay and clayey silt are shown in Fig.4(a) and Fig.4(b), respectively. In case of silty clay at dry of OMC, the USS was higher than that of the other two moisture contents; however, in the case of clayey silt, soil compacted on wet of OMC yielded a higher USS value than at OMC and dry of OMC.

As the moisture content varied from dry of OMC to wet of OMC the USS of silty clay decreased, while the USS of clayey silt increased with an increase of moisture content (Fig. 4(c)). The effect of compaction on the percentage change in the shear strength ratio (SSR) (ratio of USS of soil with reinforcement to USS of soil without reinforcement) of soil with 2% root mass is shown in Fig.4(d). It is clear from figure that change in percentage of shear strength of clayey silt was less than that of silty clay.

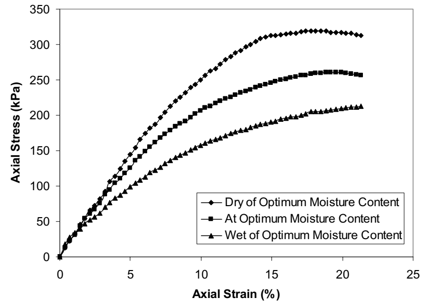

Fig. 4(a) Silty Clay with 2% Root Mass.

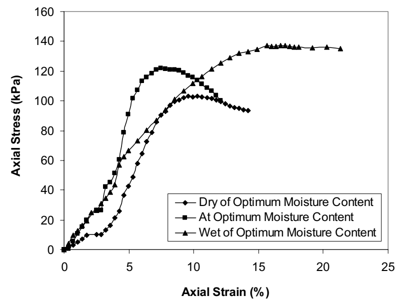

Fig. 4(b) Clayey Silt with 2% Root Mass.

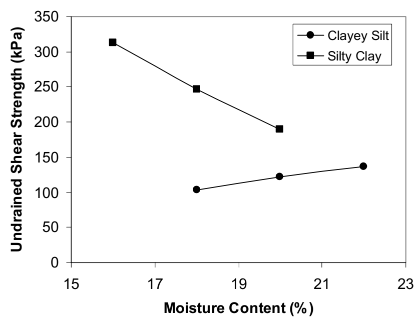

Fig. 4(c) Shear Strength of Soils with Root Mass of 2%.

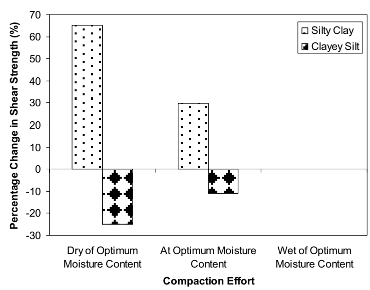

Fig. 4(d) Percent Change in SSR for 2% Root Mass.

Effect of Root Mass on the Slope Stability

The Factor of Safety (FS) of an infinite slope is calculated from Eq.1.

$$FS = \frac{c}{\gamma H \cos^2 \beta \tan \beta} \quad (1)$$

Where: FS = factor of safety; c=cohesion; γ = unit weight of soil; H = height of the sloped structure; β = slope angle. Figure 5 shows the variation of slope angle with $c/\gamma H$ for FS of 1.5 and 1.2.

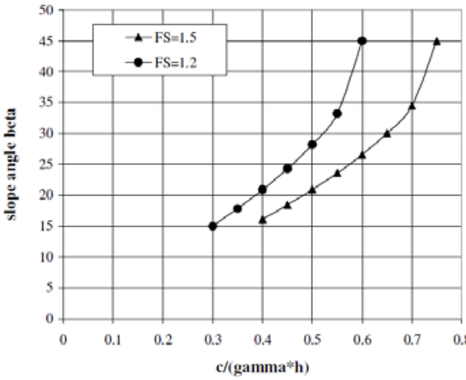

Fig. 5 Variation of Slope Angle with $c/\gamma H$

An increase in the percentage of root mass will increase the strength of the soil. This increased strength also increases the cohesion of the soil. The effect of increasing cohesion on the slope angle at the FS of 1.2 and 1.5 is shown in Fig.6(a) and Fig.6(b), respectively. With the increasing percentage of cohesion (and increasing percentage of root mass) the soil strength and slope angle increase. This indicates that the root mass present in soil acts as reinforcement, and thus increases the FS.

CONCLUSIONS

The following are the major findings of this study:

1. USS with root mass of 2% increased 240% for silty clay and 160% for clayey silt compared to strength without root mass.
2. The silty clay compacted at dry of OMC treated with root mass of 2% gave maximum USS when compared to optimum and wet of OMC.
3. The increase in percentage of root mass increases the allowable slope angle in the sloped structures.

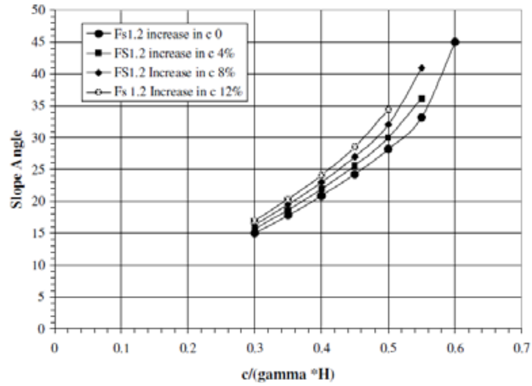

Fig. 6(a) Effect of 'c' Increase on Slope with FS = 1.2.

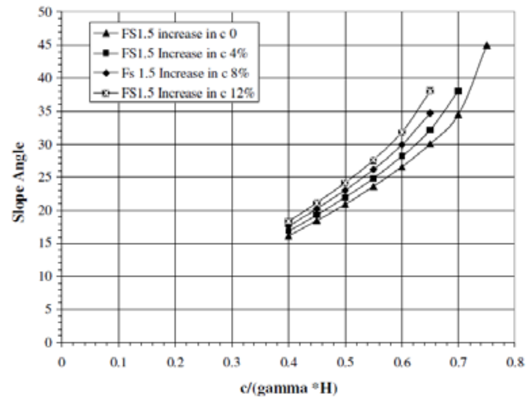

Fig. 6(b) Effect of 'c' Increase on Slope with FS = 1.5.

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