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Evaluating the use of lemon grass roots for the reinforcement of a landslide-affected soil from Nilgris district, Tamil Nadu, India

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Abstract
For many centuries, man has been concerned with stabilizing soils in order to either prevent them from being easily eroded or to make them better suited for construction such as for earth building and road construction purposes. Attempts have been made to utilize many natural, synthetic or waste materials for such soil stabilization. Plants have been used as soil cover to prevent erosion and protect slopes. However, there is need to evaluate the engineering characteristics of soils reinforced with plant roots. Consequently, this research work was aimed at investigating the effects of the reinforcement of a landslide-affected soil using the roots of a locally-available plant on the strength and permeability properties of the soil. The natural moisture content, specific gravity, particle size distribution, Atterberg limits, compaction characteristics, shear strength, unconfined compressive strength (UCS) and permeability of the natural (landslide-affected) soil were determined. Results obtained for the natural landslide-affected soil were compared with those of the soil sample admixed with varying proportions (1%, 2%, 3% and 4%) of lemon grass roots. The result shows that the shear strength and UCS of the soil having 4% lemon grass roots is almost double that of the natural soil. Also, the permeability of the soil-root matrix was sufficiently reduced. Planting lemon grass on soils located along slopes is recommended to improve its strength and minimize the ease with which water infiltrates the soil, thereby reducing the incidence of landslide and other water-induced types of slope failure.

Keywords: grass root, shear strength, permeability, bioengineering

1. Introduction
The importance of soil to man cannot be overemphasized. Most civil engineering construction works require the extensive use of soil. Soils also serve as the earth foundation on which structural foundations of buildings, roads, dams, etc., are laid. Several buildings and roads have been sited along and across earth slopes. However, several of them (with lives and properties) have been lost to slope failure such as landslide [1–3]. Consequently, several means have been adopted or proposed to improve the stability of such slope. Soil stabilization and soil reinforcement are some of the common methods of protecting slopes. The potential of using natural, synthetic or waste materials for the stabilization or reinforcement of soils have been investigated by researchers in recent times. Some of the natural, synthetic and waste materials reportedly investigated include calcium carbide residue [4], steel slag [5, 6], wastepaper sludge [7], pulverized asphalt [8, 9] and corncob ash [10].
Plants have been and are still being used to protect soils along slopes from being eroded. Their roots are known to serve as reinforcement to the soil and thereby improving their stability. Some researchers have investigated the action of root systems towards improving the stability of slopes [11, 12], but most approached their research

works from the perspective of soil science. There is no research work in open literature that has been reportedly carried out to evaluate the geotechnical properties of soils reinforced with plant roots. This research work is therefore aimed at investigating the effects of the reinforcement of a landslide-affected soil using the roots of a locally-available plant (lemon grass) on the strength and permeability properties of the soil.

2. Materials and methods

2.1. Soil sample collection and preparation

A large volume of soil samples from a landslide-affected area (Figure 1(a)) in Nilgris district, Tamil Nadu, India (11°24′ N, 76°42′ E) was collected, from which all samples for the various tests were taken. Some of the collected soil sample was packed in water-tight plastic bags (Figure 1(b)) in order to prevent the loss of moisture before the laboratory determination of its natural moisture content.

(a) (b)

Figure 1: (a) Slope failure area from where soil was collected (b) Soil samples

In the laboratory, the collected soil sample was air-dried, crushed and passed through 2.36 mm sieve for the removal of gravel portion of the soil. The soil sample was thoroughly mixed prior to conducting any laboratory test in order to ensure that the sample used is a representative of the bulk.

2.2. Plant root collection

The root of a native plant - lemon grass (Cymbopogon citratus) - was used for this study. This plant (Figure 2(a)) is readily-available in the Nilgris district of Tamilnadu. Lemon grass is a medicinal plant growing in the hilly region of Nilgris district. The root system of a matured lemon grass is known to be strong and deep [13, 14] (Poudel et al., 2000; Lekha, 2004).

(a) (b)

Figure 2: (a) Lemon grass in a field (b) Lemon grass root collection for soil stabilization studies

The lemon grasses and their roots with the soil clogged around it were collected by carefully excavating the grass-root-soil system from the subsoil, as if they were been transferred from a nursery (Figure 2(b)). They were collected in open plastic containers and watered in the laboratory, to keep the plant alive. Prior to being admixed with the soil sample in order to carry out the various laboratory tests, the roots were then separated from the grass and the clogged soil. They were washed with distilled water and kept dried. The required mass of the collected root was admixed with the soil sample to obtain the various proportions of the soil-grass root matrix. We took care in order to achieve satisfactory uniform mixtures, as far as possible.

2.3. Methods

The natural moisture content, specific gravity, particle size distribution, Atterberg limits, compaction characteristics, shear strength, unconfined compressive strength and permeability of the natural (landslide-affected) soil were determined in accordance with Indian Standards [15].

The compaction characteristics, shear strength, unconfined compressive strength and permeability of the soil samples were also determined for the soil sample admixed with each of 1%, 2%, 3% and 4% of the lemon grass roots, by dry weight of the soil. This range of percentages of lemon grass root was chosen because it was observed that it better simulates the typical lemon grass root distribution in a soil. Samples for the unconfined compressive strength (UCS) and direct shear tests are shown in Figure 3.

The permeability was conducted for three different densities of the sample (1200 kg/m^3, 1450 kg/m^3 and 1600 kg/m^3) using constant head permeameter.

The UCS and direct shear strength were determined for the sample having a density of 1200 kg/m^3. The samples with 1200 kg/m^3 were chosen for the strength (UCS and direct shear) tests because this density will provide the lowest soil strength values of the three different densities chosen for the permeability tests. Thus, we considered the worst scenario.

(a) (b)

Figure 3: Samples during (a) UCS and (b) shear strength tests

3. Results and discussion

3.1. Properties of soil sample

The soil used is reddish-brown and has an average natural moisture content of 10%. It has a specific gravity of 2.6. The particle size distribution of the soil sample is shown in Figure 4. About 26% of the soil particles are finer than the 75 µm sieve. According to the Unified Soil Classification (USC) and American Association of State Highway and Transportation Officials (AASHTO) systems, the soil is clayey sand (SC) and A-2-6, respectively. Table 1 provides a summary of the geotechnical properties of the natural soil.

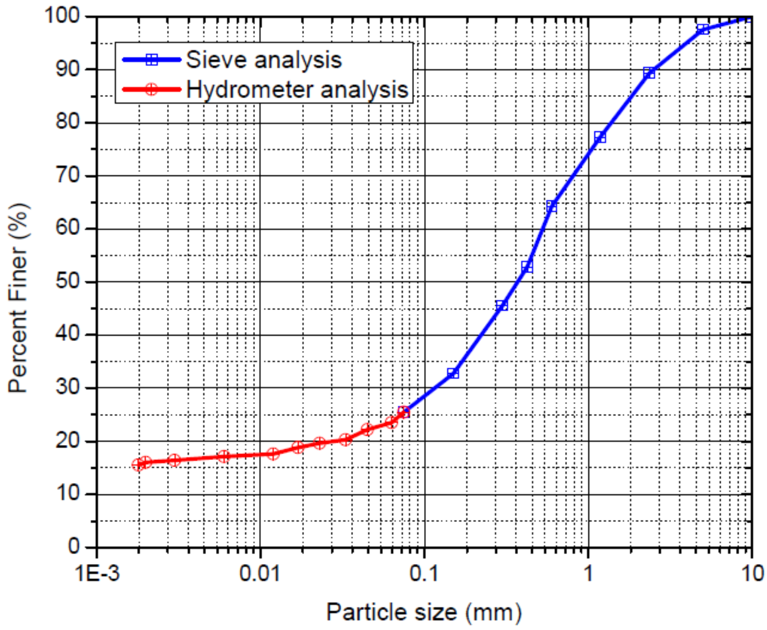

Figure 4: Particle size distribution of soil sample

Table 1: Geotechnical properties of the soil sample

S/No.	Properties	Value
1	Specific gravity	2.6
2	Liquid limit	23.37%
3	Plastic limit	10%
4	Plasticity index	13.37%
5	Maximum dry density	1.93 g/cm^3
6	Optimum moisture content	12%
7	Cohesion, c	5 kN/m^2
8	Angle of internal friction, Φ	28°
9	Shear strength	135.3 kN/m^2
10	Unconfined compressive strength	34.2 kN/m^2
11	Coefficient of permeability	6.7 x 10^{-3} cm/s

3.2. Effects of adding lemon grass roots to the soil sample

3.2.1. Effect on unconfined compressive strength

The effect of varying the lemon grass root content in the soil on the UCS of the soil is graphically illustrated in Figure 5. The UCS of the soil-root mixtures increased with increasing root content in the soil. The UCS of the soil with 4% root content almost doubled that of the natural soil sample. The predominance of sand in the soil (with only about 17% clay present) can be attributed to the generally low UCS and cohesive force within the particles of the natural soil. However, the lemon grass root serves as a reinforcement of the natural soil fabrics.

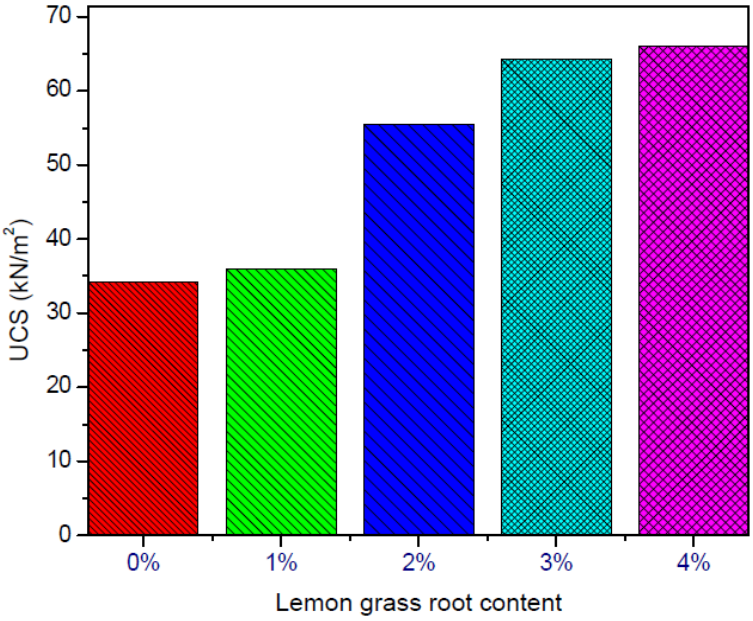

Figure 5: Variation of UCS with lemon grass root content

3.2.2. Effect on shear strength

Soils usually fail mostly due to shear failure. Therefore, it is necessary to evaluate how the shear strength of the soil sample will be affected by varying proportion of the lemon grass root system. The variation of shear strength of the soil with the lemon grass root content is presented in Figure 6. Figure 6 shows that the shear strength of the soil progressively increased with every increase in the lemon grass root content. The root system improves the shear strength of the soil in similar way as fibers do. The shear strength of the soil with 4% root content was significantly improved. This increase in shear strength can be attributed to the tensile strength of the root. The results of the UCS and shear strength of the root-reinforced soil samples justify the recently increasing interest in the use of vegetation for slope stabilization [16–21].

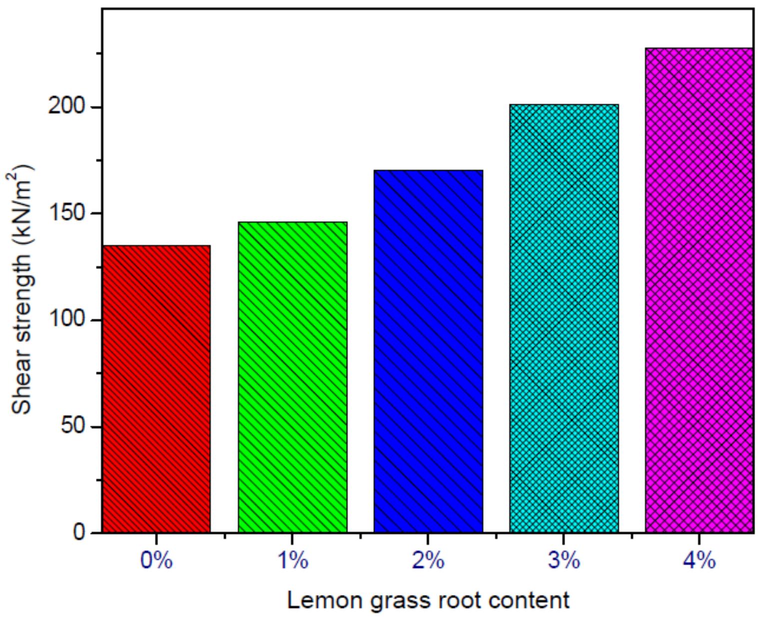

Figure 6: Variation of shear strength with lemon grass root content

3.2.3. Effect on permeability

The effects of varying the lemon grass root content in the soil on the permeability of soil samples having various densities are graphically illustrated in Figure 7. For the soil samples having densities of 1200 kg/m^3 and 1450 kg/m^3, the permeability of the root-reinforced soil decreases with increasing lemon grass root content. However, the effect of the variation of the lemon grass root content on the soil sample having a density of 1600 kg/m^3 seem not to be well-defined. The general reduction in the permeability of the soil samples with increasing lemon grass root content can be attributed to the plugging of void spaces in the soil by the root system. This reduces the pore-water pressure in the root-reinforced soil. Ghestem et al. [22] stated that "hydrological mechanisms that promote lower pore-water pressures in soil are beneficial to slope stability".

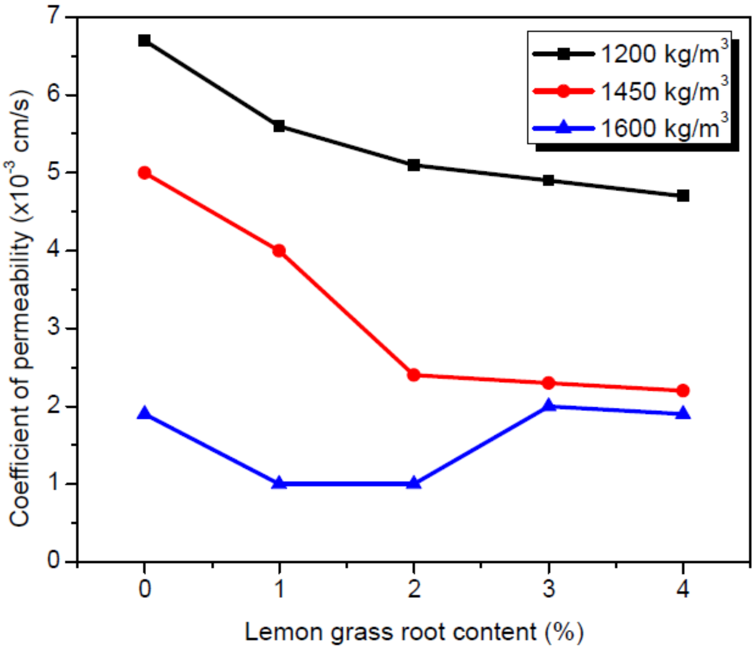

Figure 7: Variation of permeability with lemon grass root content

Even though the use of vegetation for slope stabilization and erosion control is not new, these results are significant because of the need to quantify the effect of reinforcing root on soil strength [16] and permeability.

4. Conclusion

This research work investigated the effect of reinforcing a soil sample (with varying proportions of lemon grass root) on its strength and permeability characteristics. The results obtained show that the strength properties of the soil samples were improved by the application of the root to the soil. The mixture of the soil sample with 4% lemon grass root increased its UCS and shear strength by 93.3% and 68.5%, respectively. The permeability of the soil was generally reduced by the application of the lemon grass root. For the sample having densities of 1200 kg/m3 and 1450 kg/m3, the mixture of the soil sample with 4% lemon grass root decreased its permeability by 29.9% and 56%, respectively.

Consequently, lemon grass root is a low-cost material that can be effectively used to improve the stability of soils by improving their shear strength and UCS, and reducing their permeability. Lemon grass (plant) roots can be employed to reinforce or stabilize soils along slopes in order to prevent slope failure.

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