Paper ID: CE 0366

Improvement of Shear Strength Properties of Organic Soil Using Sand Column

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Abstract

Organic soils are the amalgamation of rotted plants and endured rock materials. The main problem of organic soil is that it is fragile in shear strength and its deformation characteristics are massive for its high compressibility, high saturation, low density, and low shear strength. These characteristics present some challenges and restrictions for the construction of civil structures, particularly in the geotechnical discipline. It is necessary to identify the properties of organic soil and taking proper initiative to overcome the probable risk in any engineering practice. One of the common practices in the geotechnical engineering field to minimize the settlement and ameliorate the load-bearing capacity of problematic soils is the use of sand columns. In this research, an attempt has been taken to discuss the outcomes of a sequel of direct shear tests undertaken to analyze the response of organic soil with various sand columns. The tests concentrated on the effect of various sizes of sand particles (coarse sand, medium sand and mixed sand of coarse-medium particles) used in the columns and the different sizes of sand columns in sample soil. In this research, engineering properties like the angle of internal friction and cohesion were determined from the direct shear test. The tests results revealed that the variation in the size of sand grains in the added sand column and the percentage of organic soil has effects on the stabilized strength of the soil.

Keywords: *Sand column; organic soil; direct shear test; shear strength; stabilized soil.*

1 Introduction

Organic soils form through the condensation of fragmented organic material, often in water-saturated or partially submerged areas with suitable topography and climate. They are often found in thick layers in certain primitive locations, composed of carbon-based material originating from past or current living organisms. The formation of organic soils (shown in figure 1) relies on essential components: water, air, minerals, and organic material, governed by the physical attributes of the soil. Parameters like bulk density, porosity, wetting and drying behavior, loss of ignition, and moisture relation define their properties [1]. The crucial biological, chemical, and physical attributes of soil, encompassing shear strength, compressibility, and structure, are regulated by existing organic matter within organic soil. This type of soil is distinguishable by its elevated compressibility and diminished shear strength [2]. The organic content significantly influences soil behavior. As organic content increases, optimal water content rises and maximum dry density decreases, affecting compressibility as well [3]. Habbi [4] arrived at similar conclusions. Zbar et al. [5] found that heightened organic matter led to decreased specific gravity, resulting in lowered optimal water content and maximum dry density. Organic soil, characterized by a mixture of organic substances, embodies soft soil characteristics, posing challenges for civil engineering structures due to poor ground conditions and foundation issues [6].

Engineers employ diverse methods to enhance soil quality. Previous research results show chemical admixtures, deep mixing, jet grouting, and cement have been utilized. Sand columns are a prevalent strategy to bolster bearing capacity and settlement properties of weak ground. These columns, made of compressed granular material in cylindrical perforations, improve strength and consolidation of soft soils. A sand column's load-bearing capacity relies on frictional properties, foundation flexibility, and lateral pressure in the soil mass [7-9].A study by Aarthi et al. (2022) [10] investigated using M sand and quarry dust to bolster soft clay deposits, enhancing bearing capacity and reducing settlement. Kalantari et al. (2009) [11] used ordinary Portland cement (OPC) to strengthen peat soil, noting improved load-bearing capacity with increased curing time. In Black et al.'s work (2007) [12], vertical sand columns enhanced shear strength in soft kaolin clay samples. Canakci et al. (2017) [13] found sand column reinforcement improved compressibility and shear strength in fibrous peat. This research aims to stabilize organic soil by reinforcing sand columns of varying diameters (1.5 and 2 cm), comparing shear strength parameters through direct shear tests.

Figure 1. Organic soil

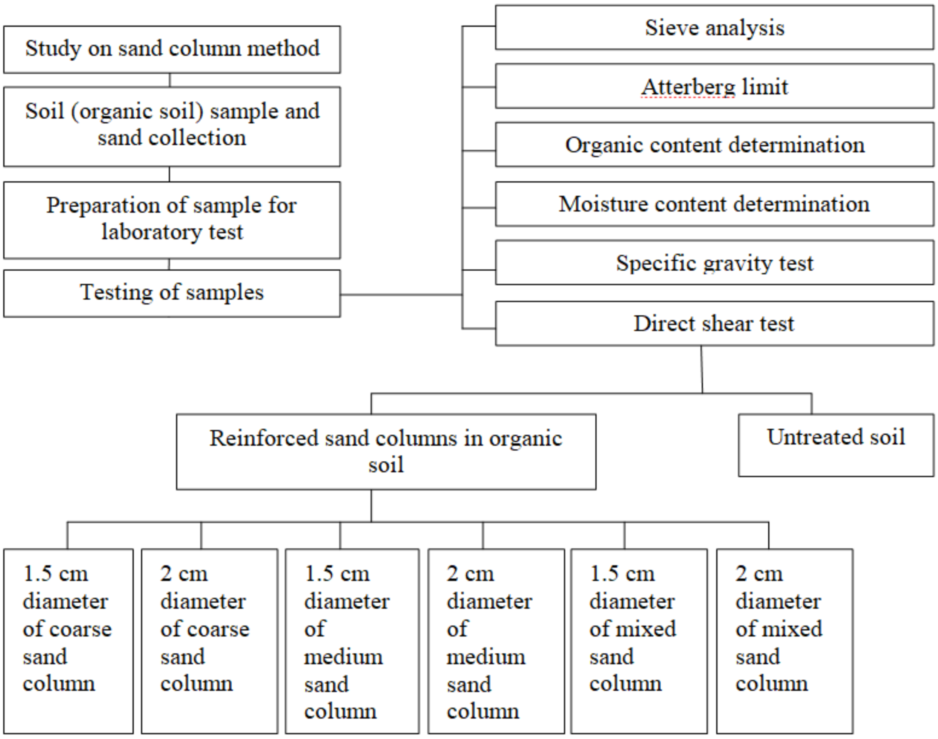

Figure 2. Flow chart of the study

2 Methodology

The study strictly adhered to American Society for Testing and Materials (ASTM) standards within the university's geotechnical lab. Initial tests determined soil classification through Atterberg limit tests. A subsequent evaluation of organic content revealed 46.75% in the soil sample, in accordance with ASTM's classification of organic soils. After confirming organic status, diverse assessments, including specific gravity and moisture content, were conducted. Sieve analysis was employed for sandy soil, distinguishing gravel, clay, and silt. The sandy soil sample was then meticulously separated into coarse, medium, and fine sand components, following the Unified Soil Classification System (USCS) criteria.

This research's main objective was to enhance the angle of internal friction and the shear strength characteristics of problematic organic soil. This was achieved through a series of direct shear tests employing diverse sand particle columns of varying sizes. These columns were strategically positioned at the shear box's center point, enclosing the organic soil. Each particle category, whether coarse, medium, or a combination thereof, was represented by two distinct columns with diameters of 1.5 cm and 2 cm. The experiments were executed for each particle column as per the depiction in Figure 2. Additionally, an untreated soil's direct shear test was conducted to evaluate the improvements made to the modified soil. Seven tests were conducted. The columns were precisely placed in the shear box center using manually crafted cylindrical paper tubes shown in figure 3.

Figure 3. Direct shear test set up

3 Experimental works

This study aimed to enhance the shear strength of organic soil by establishing different types of sand columns to stabilize the untreated soil. The eligibility of the organic soil was assessed through tests for organic content, moisture content, and specific gravity (Table 1). The classification of the organic soil followed USCS guidelines using a plasticity chart. To comprehend the shear strength characteristics of the untreated soil, direct shear tests were conducted. Subsequently, after implementing sand columns within the untreated soil, several direct shear tests were performed using the procedure depicted in Figure 3. Additionally, grain size analysis tests were conducted for the sands in the study.

Table 1. Name of different tests and their results.

Test	Result
Organic Content Determination	46.75%
Moisture Content Determination	139.825 % (avg)
Specific Gravity Test, G_s	1.835 (avg)

3.1 Grain size analysis (sieve analysis)

To assess the arrangement of soil particles, the sieve analysis test was performed. Figure 4 displays a combined gradation curve, and the distribution percentages of different particles are outlined in Table 2. The soil retained and passing through the 4.76mm sieve accounted for 5.62% and 93.98%, respectively. Furthermore, a passing rate of 0.4% was observed for the No. 200 sieve.

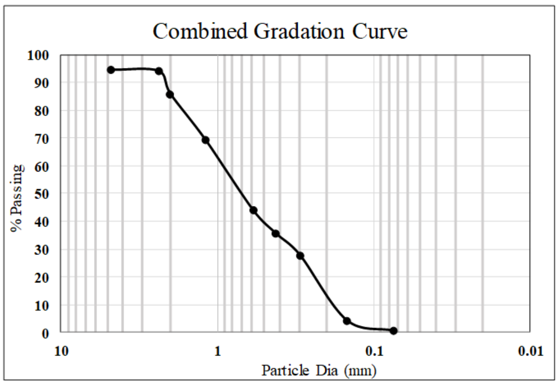

Figure 4. Grain size distribution curve (sieve analysis)

Table 2. Analysis of particle size distribution

Particles	Percentage of particles
Gravel (%)	5.62
Sand (%)	93.98
Fines (%)	0.4

3.2 Atterberg limit test

As per the USCS, a liquid limit of 50% or below categorizes the soil as low plastic clay or silt. The atterberg limit test indicated a liquid limit of 37%, a plastic limit of 27%, and a plasticity index of 10%. Utilizing the Aurthur Casagrande plasticity chart in Figure 5, the soil was classified as low plastic silty organic soil (OL).

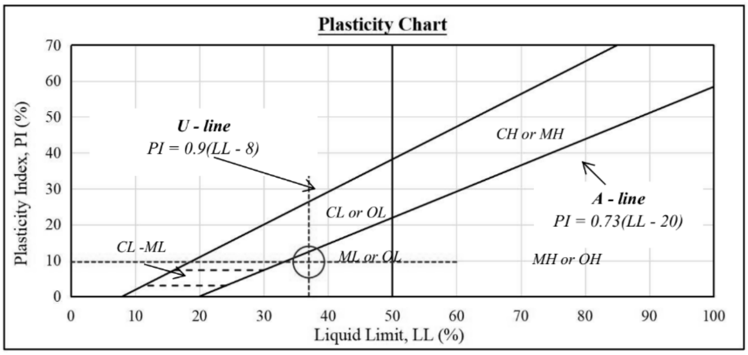

Figure 5. Soil classification using Aurthur Casagrande plasticity char

3.3 Direct shear test

Figure 6 displays the direct shear test results for different samples. Linear relationships with gradual increases were evident across various sand column diameters. The 2cm diameter medium sand column exhibited the maximum shear stress at 18.1 psi, while the 1.5cm diameter coarse sand column showed the lowest value of 14.6 psi.

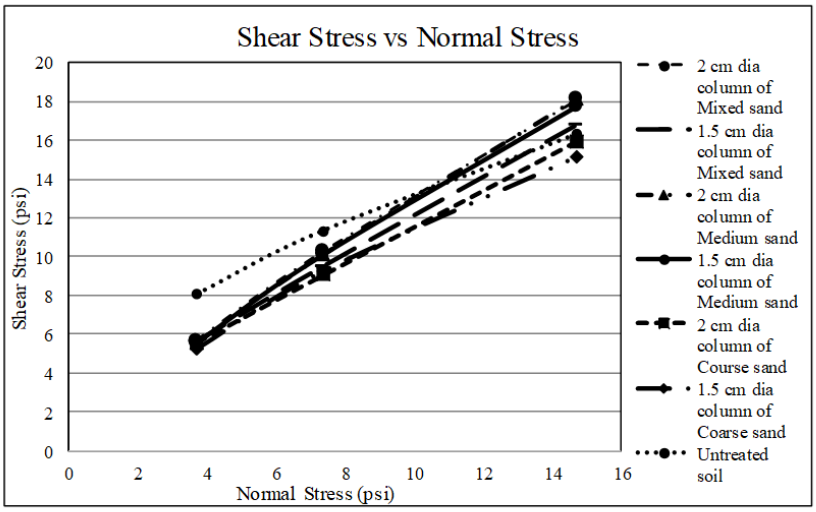

Figure 6. Shear stress vs normal stress of treated and untreated soil

4 Analysis result

The alterations in friction angle and cohesion are readily discernible in Figure 7 and Figure 8 for the treated soil. Figure 7 illustrates an evident rise in the internal friction angle within the treated soil. In treated soil, a 2cm coarse sand column and a 1.5cm column show an increment of 18.32% and 13.66%, respectively, in the internal friction angle compared to untreated soil. Correspondingly, in the medium sand column, the 2cm and 1.5cm diameters exhibit increments of 32.92% and 30.38%, respectively. In the mixed sand column, the 2cm and 1.5cm diameters

display increments of 32.35% and 23.67%, respectively. The void ratio between coarse sand particles surpasses that of medium sand particles, leading to a reduction in the internal friction angle as void ratio expands. The minimal void ratio among medium sand particles results in a greater internal friction angle. Consequently, the hierarchy of increasing particle percentages, as depicted in the chart, is as follows:
Medium sand > Mixed sand > Coarse sand

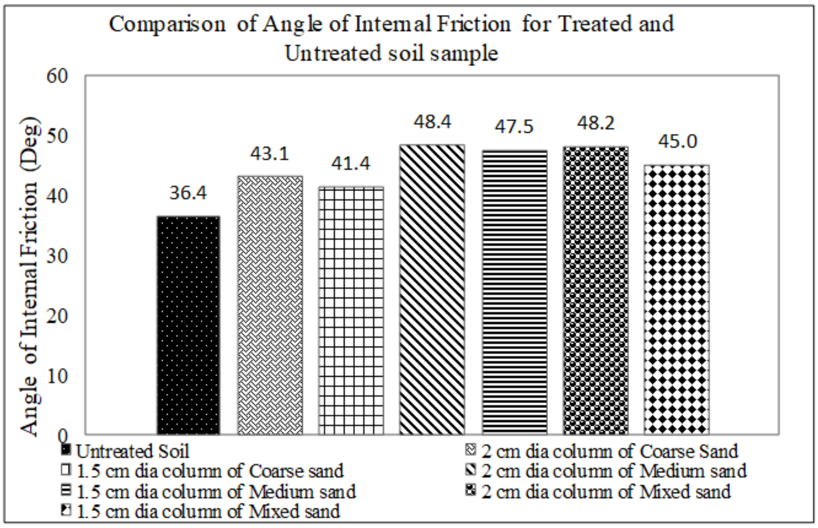

Figure 7. Bar chart of the angle of internal friction of treated and untreated soil.

Sand column diameters directly impact the internal friction angle, increasing with diameter enlargement. A larger sand column surface area compared to the organic soil surface results in higher internal friction angle. Notably, in the medium sand category, the percentage increase for a 2cm diameter (32.96%) exceeds that of a 1.5cm diameter column (30.38%). Figure 8 depicts cohesion variations in treated and untreated organic soil. Treated soil shows decreased cohesion for 2cm and 1.5cm coarse, medium, and mixed sand columns: 61.17%, 57.77%, 71.37%, 67.97%, 68.65%, and 63.21%, respectively, compared to untreated soil. Larger diameters within each sand particle category (coarse, medium, mixed) align with reduced cohesion.

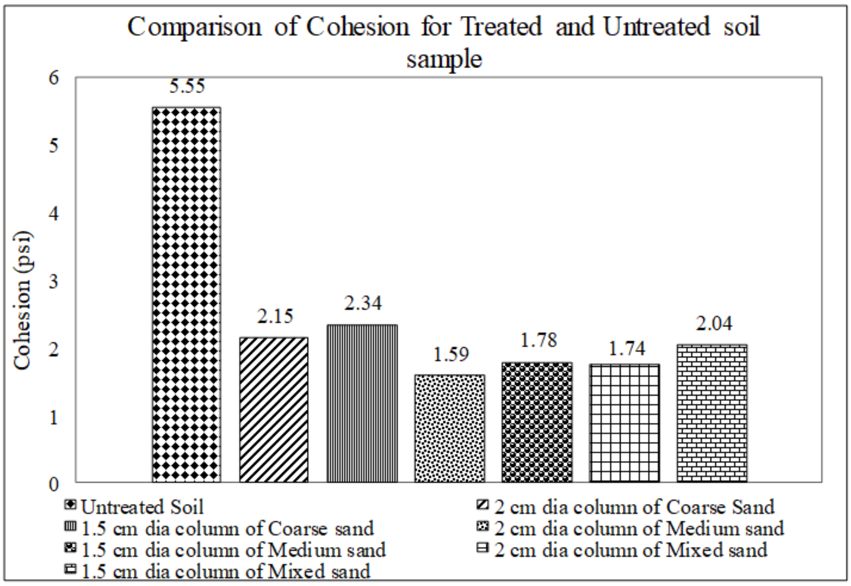

Figure 8. Bar chart of cohesion of treated and untreated soil

5 Discussion and Conclusion

The aim of this study was to enhance the properties of flexible organic soil by reinforcing it with columns of varying sizes of sand particles. Two different column diameters were employed in the experiments, and three sizes of sand particles were used to create these columns at the shear box's center. Among the sand particles, medium sands exhibited a higher internal angle of friction than coarse and mixed sands. Increasing sand column diameter or the ratio of reinforced sand column surface area to organic soil led to higher internal angle of friction. In each particle category, a 2cm diameter column had a greater internal angle of friction than a 1.5cm diameter column. Cohesion decreased in treated soil compared to untreated soil. Medium sand columns exhibited a greater reduction in cohesion than coarse and mixed sand columns in organic soil. Increasing sand column diameter resulted in reduced cohesion. The laboratory tests revealed that treated soil's compressibility decreased compared to untreated soil, owing to the use of sand columns. Given the limitations imposed by the COVID situation, further research with additional column diameters and recycled materials could provide deeper insights into improvements.

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