EFFECT OF SUCTION ON UNCONFINED COMPRESSIVE STRENGTH OF CLAYEY SOILS WITH DIFFERENT SAND CONTENTS

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ABSTRACT

This paper presents the investigation of influence of matric suction on unconfined compressive strength of clayey soils with different sand contents. The matric suction within clay samples with sand contents of 0, 20 and 40 percent was applied using the suction chamber. The results show that the unconfined compressive strength increased with increasing matric suction for the matric suction range less than 50 kPa but decreased with increasing matric suction for the suction range greater than 50 kPa. The results also show that the unconfined compressive strength increased with increasing sand content for all values of matric suction. Furthermore, the values of unconfined compressive strength normalized by matric suction for the samples with different sand contents trend to converse to each other at high value of matric suction.

Keywords: matric suction, clay, unconfined compressive strength, suction chamber.

INTRODUCTION

In geotechnical analysis and design, the undrained shear strength is a very important parameter. It can be obtained from both laboratory and field tests. The common laboratory test used to determine the undrained shear strength is the unconfined compression tests. This type of test is typically performed on saturated clay sample taken from the soil layer below the groundwater table.

The saturated and dry conditions are generally assumed for the soil below and above water table, respectively. However, almost 40 percent of natural soils on the earth surface are in an unsaturated state. This type of soils can be found in arid and semi-arid regions. Moreover, the unsaturated soils can be encountered in civil engineering works, such as compaction works in construction of roads, dams and other types of embankment.

Several model have been proposed to predict the shear strength of unsaturated soils at different values of suction (e.g., Alonso *et al*., 1990; Fredlund *et al*., 1996; Vanapalli *et al*., 1996; Sun *et al*., 2000; Toll and Ong, 2003; Khalili *et al*., 2004; Tarantino, 2007; Sheng *et al*., 2008). However, the investigation on influence of sand content on the strength of unsaturated clays is very rare.

Thus, the main objective of this study is to investigate the influence of matric suction on unconfined compressive strength of clayey soils with different sand contents. The tests results are presented to clarify the influences of suction and sand content on the strength of unsaturated clays.

EXPERIMENTAL PREPARATION AND TEST MATERIAL

Suction chamber

In this study, the matric suction within the soil samples was increased using the suction chamber as shown in Figure-1. The suction chamber was capable of independent control of pore air pressure at the top and the surrounding surfaces of the specimen and the pore water pressure at bottom boundary of the specimen. The pore water pressure was controlled through a high air entry ceramic disc. The ceramic disc was attached to the base of apparatus using epoxy glue to prevent the air flowing to the water compartment via its surroundings. The properties of the ceramic disc used in this study are shown in Table-1. The suction within the specimen is equal to the difference between the pore air and pore water pressures at equilibrium (Hilf, 1956). The matric suction can be defined as,

$$s = u_a - u_w \tag{1}$$

in which, s is the matric suction, u_a is the pore air pressure and u_w is the pore water pressure.

Table-1. Physical properties of high air entry ceramic disc.

Porosity (%)	32
Permeability (cm/sec)	2.59×10^{-3}
Maximum pore diameter (μm)	0.16

Prior to each test, the flushing technique similar to that used by Tolled (1988) was performed to saturate the ceramic disc and the pore water pressure system. The chamber was first assembled as shown in Fugure-1 and was then filled with de-aired water with pressure of 600 kPa. The water was allowed to flow through the ceramic disc while the water at the base of ceramic disc was maintained at the atmospheric level. The drainage line was closed for at least 2 hours after collecting 200 cm^3 of water flow. The additional flushing process was conducted to ensure that the ceramic disc was fully saturated.

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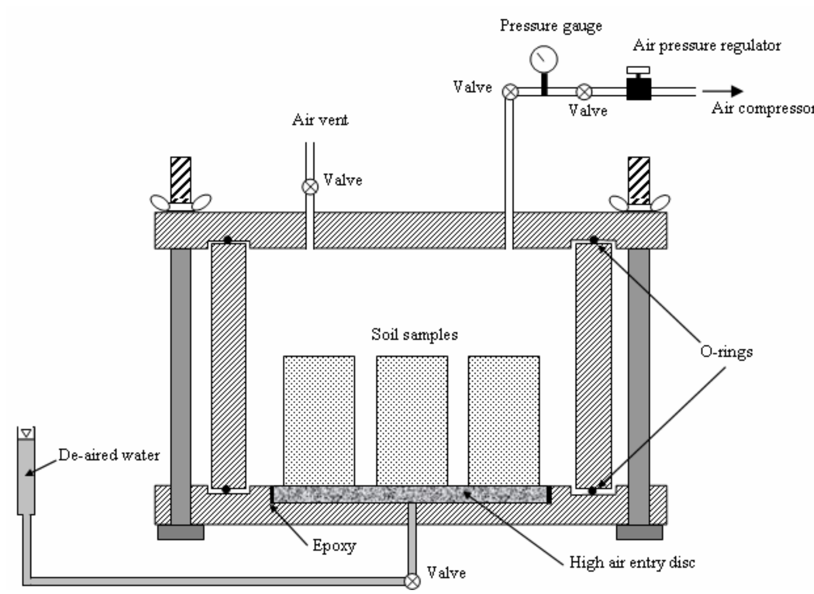

Figure-1. Schematic diagram of suction chamber.

Test materials

The experiments were performed on kaolin clay samples with silica sand contents of 0, 20 and 40 percent. The values of the specific gravity of kaolin and silica sand are 2.62 and 2.77, respectively. The gradation curves of kaolin and sand silica are shown in Figures-2 and 3. The liquid limit, plastic limit, plastic index and soil group of the clay samples with different sand contents are given in Table-2.

Table-2. Index properties of kaolin clay samples with different sand content.

Property	0% sand	20% sand	40% sand
Liquid limit	34	27	18
Plastic limit	23	18	10
Plastic index	11	9	8
Soil group	CL	CL	CL

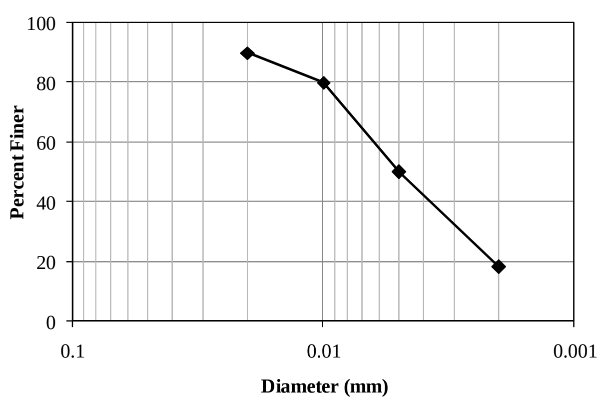

Figure-2. Gradation curve of kaolin.

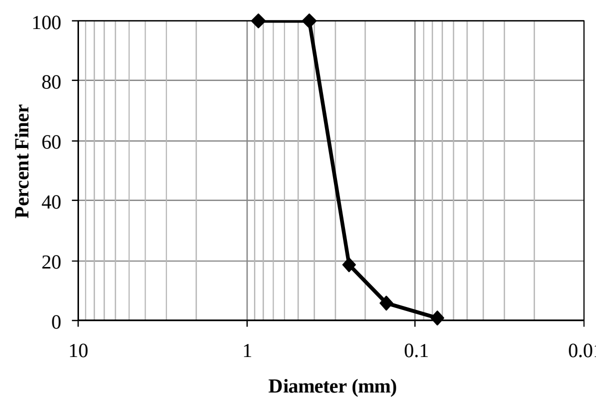

Figure-3. Gradation curve of sand.

Sample preparation

The sample paste with water content at liquid limit was prepared. The sample was then placed into the cylindrical molds with diameter of 38 mm and height of 76 mm, which was setup in the suction chamber as shown in Figure-1. The molds were carefully shaken during this process to prevent any air entrapment. The chamber was then assembled and the air pressure was applied from the top of the chamber. The matric suction within the samples was increased using the axis translation technique. The water was allowed to flow through the high air entry disc. The equilibrium was reached when there was no water flow out from the high air entry disc for 24 hours. It took 2 to 3 days for this stage. The matric suction within the sample was the difference between applied air pressure and water pressure at the bottom of the high air entry disc (atmospheric pressure for this study).

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Test procedure

A series of unconfined compression tests was performed on the samples with different sand contents and matric suction. The vertical load and displacement were recorded during testing. The details of test procedure are described in ASTM D2166.

TEST RESULTS AND DISCUSSIONS

The test results are presented in terms of axial stress against axial strain, which are defined as,

$$\sigma_a = \frac{P}{A} \quad (2)$$

$$\varepsilon_a = \frac{\Delta L}{L_o} \quad (3)$$

in which, σ_a is the axial stress, ε_a is the axial strain, P is the compressive load, A is the area of specimen, ΔL is the change in specimen length and L_o is the initial length of specimen.

Figures-4 to 6 shows the relationship between axial stress and axial strain at different value of matric suction for clay samples. It can be noticed that the stress-strain relationship shows strain softening behavior after the peak stress value in most cases. Moreover, the unconfined compressive strength, which is the peak stress value, increased with increasing matric suction for the matric suction range less than 50 kPa but decreased with increasing matric suction for the suction range greater than 50 kPa as shown in Table-3 and Figure-7. The results also show that the unconfined compressive strength increased with increasing sand content for all values of matric suction.

Figure-8 shows the plot between normalized values of unconfined compressive strength and matric suction. It can be noticed that the curves trend to converse to each other at high value of matric suction.

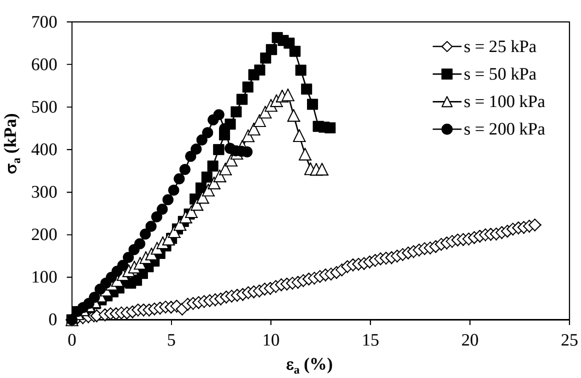

Figure-4. Relationship between axial stress and axial strain at different values of matric suction for clay samples with sand content of 0%.

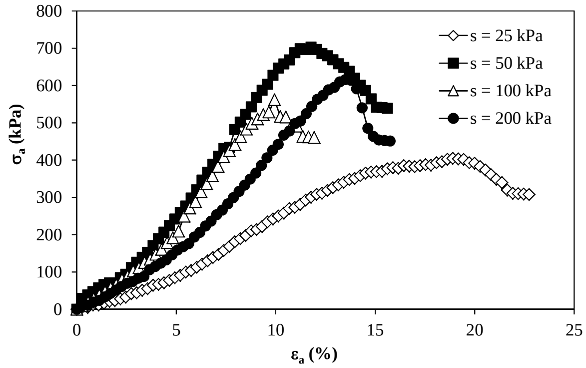

Figure-5. Relationship between axial stress and axial strain at different values of matric suction for clay samples with sand content of 20%.

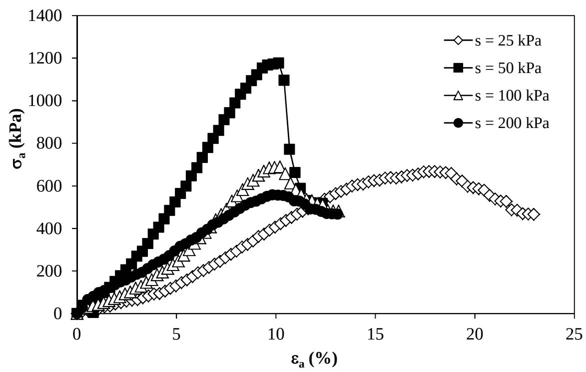

Figure-6. Relationship between axial stress and axial strain at different values of matric suction for clay samples with sand content of 40%.

Table-3. Unconfined compressive strength of clay samples with different values of matric suction.

Matric suction (kPa)	**q_u at different sand content** (kPa)		
	0 %	**20** %	**40** %
25	223	405	667
50	662	703	1177
100	528	562	688
200	482	616	558

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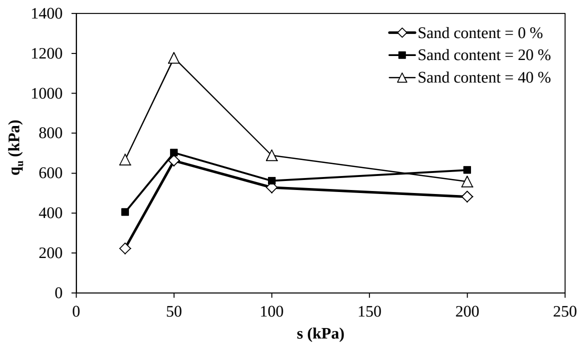

Figure-7. Variation of undrained shear strength with matric suction at different values of temperature.

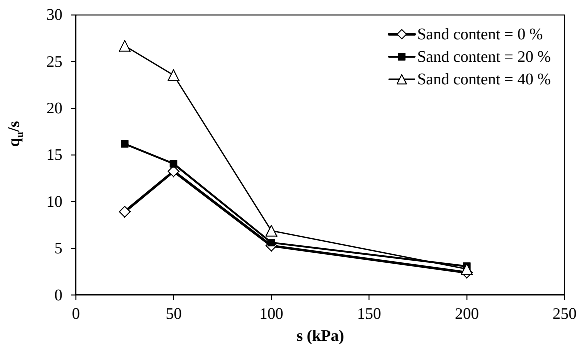

Figure-8. Relationship between normalized values of unconfined compressive strength and matric suction.

CONCLUSIONS

The influence of matric suction on unconfined compressive strength of clayey soils with different sand contents was investigated in this study. The matric suction with in clay samples with cement contents of 0, 20 and 40 percent was applied using the suction chamber. The results show that the unconfined compressive strength increased with increasing matric suction for the matric suction range less than 50 kPa but decreased with increasing matric suction for the suction range greater than 50 kPa. The results also show that the unconfined compressive strength increases with increasing sand content for all values of matric suction. Furthermore, the values of unconfined compressive strength normalized by matric suction for the samples with different sand contents trend to converse to each other at high value of matric suction.

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