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SHEAR STRENGTH BEHAVIOUR OF UNSATURATED FINE GRAINED SOILS USING CONVENTIONAL TESTS

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ABSTRACT

Unsaturated soils mechanics is new and emerging branch of soil mechanics in which shear strength and related parameters of partially saturated soils play significant role. There are various methods available to measure the shear strength of partially saturated soils like modified triaxial or modified direct shear test equipment with provisions for suction control, but they are usually difficult, expansive and slow moving. In this research an easy technique has been put to use to measure the shear strength of partially saturated soils. In this study combination of filter paper, simple direct shear test and unconfined compression test is used to determine the shear strength of partially saturated or unsaturated soils. In this study, soil water characteristic curve of the soil is generated by the filter paper technique, and then number of simple or conventional direct shear test and unconfined or axial compression tests are conducted to measure the shear strength and undrained shear strength of the soil respectively. To predict shear strength behavior of partially saturated soils with better consistency, the experimentally obtained tests results were compared the results obtained from semi-empirical procedures.

In this study non-linear regression analysis were carried out to best fit the soil water characteristic curve established by using filter paper method into the models given by Fredlund & Xing (1996) and Van Genutchen (1980) by varying the curving fitting parameters. This study has reaffirmed that with rise in moisture content, suction values decrease. The test results have also shown that as the matric suction increases, the strength of partially saturated soils also increases. This variation of shear strength with matric suction (shear strength envelopes) for different net normal stress was observed to be non-linear. The shear strength parameters like apparent cohesion ‘c’ and apparent cohesion ‘ϕ’ also shows direct relation with the matric suction in the soil. The unconfined compressive values also shows the same direct trend with matric suction. Lastly, the experimentally determined test results were compared with the theoretically predicted test results. It was found that experimentally determined results were in agreement with the results obtained from semi-empirical procedures.

This combined method is a very simple technique for analysing the shear strength of partially saturated soils as it can be utilized in almost every soil mechanics or geotechnical engineering laboratories.

Introduction

There are abundant soil materials present in nature whose behavior and performance does not correspond with the codes and theories of classical or conventional soil mechanics for saturated and dry soil. In most of the engineering projects, soil parameter are evaluated and modelled using saturated condition of the soil. However in the actually sense, soil rarely exist in a state of complete saturation. This is more so in the tropical arid and semi-arid region of the world where water table are significantly deeper from the surface or ground level.There are many areas present on earth where the ground water table is found deep below the ground surface. As a result of this all the phases of soil (i.e, soil, air, water and soil air water interface)are present and it therefore makes the study of partially saturated soil mechanics more difficult to comprehend. Soils found in areas where unsaturated conditions are prevailing have comparatively higher strength because of the negative pore water pressure or matric suction existing in the soil (Lu and Likos 2004). Since unsaturated soils contain water-contents below their full-saturation levels, therefore, voids present in partially saturated soils are occupied by both liquid and the air.

Problem statement

In past few decades, number of researchers have established semi-empirical techniques used to forecast the shear strength of partially saturated soils. Inputs like effective shear strength parameters (at 100% saturation) and soil water characteristic curve are used in the semi-empirical methods for calculating the shear strength of partially saturated soils. Since shear strength and related parameters are key issues in unsaturated soil mechanics, researchers developed new testing equipment for evaluation of shear strength and other related parameters. These new or modified equipment includes modified direct shear or triaxial shear equipment. But these equipment takes much time and require extensive laboratory services, which are costly.

In modified triaxial test, axis translation technique is used for evaluating shear strength and matric section under controlled conditions. But the problem associated with this technique is that it takes long equilibration time between water pressure and air pressure in the specimen. In addition, this technology is expansive and provides dissimilar condition in specimen relative to the natural surroundings. In partially saturated soil, atmospheric pressure and negative pore water pressure are present. To simulate these conditions in the axis translation technique, high level of air pressure is applied so that pore water pressure either equal to or excess of the atmospheric pressure. To keep the matric suction in soil specimen same as that in natural condition, different air pressure and water pressure are applied in axis translation technique. With the help of present technology it is yet to be proved if this method used in axis translation technique would disturb the test results or not (Xing et al. 2016). For these reasons, the application of shear strength of partially saturated soil, in practice, has been limited.

Objectives of the study

The main objective of this work is to study the Shear Strength behavior of unsaturated soils using conventional direct shear test and unconfined compression test. The detailed research work is summarized as:

i. To determine the engineering properties of samples obtained.
ii. To determine the matric suction of soils at different degree of saturation using filter paper technique.
iii. To determine the shear strength and undrained shear strength of soil using conventional direct shear test and unconfined compression respectively at different degree of saturation.
iv. To study the effect of matric suction on the shear strength of soil.
v. To study the effect of matric suction on shear strength parameters.

vi. To compare the data obtained from conventional methods with semi-empirical techniques to forecast the shear strength of unsaturated soil with better consistency.

Materials and Experimental Testing Program

Soil

The soil used in this study was collected from National Institute of Technology, Srinagar, (Latitude 34˚07'18''N, Longitude 74˚50'79''E) at a 1m depth from the natural earth surface at three different sites, to avoid the influence of organic matter. Soil sample were collected from area near transportation engineering lab (Site 1), playground near basketball court (Site 2) and area near guest house (Site 3). Soils collected were airtight and carried to laboratory for studying the in-situ properties. The study of previous study on this soil reveals that soil in this campus is fine-grained dominated by silt content (Mir 2019).

Whatman Grade 42 Filter paper

Whatman Grade 42filter papers are ashless papers are comprehensively used for critical, investigative categorization procedures. Whatman grade 42 filter papers have best retention of all whatman ashless filter paper grades. This can retain the particles of size 2.5 μm. These ashless filter papers have maximum ash content of 0.007%.

Whatman grade 42 filter paper is used in this study to determine the Soil water characteristic curve.

Methods

Laboratory test were carried out to determine the index properties of in accordance with IS 2720. Dry soil sample was prepared for various tests to be performed in accordance with IS 2720-1 (1983).

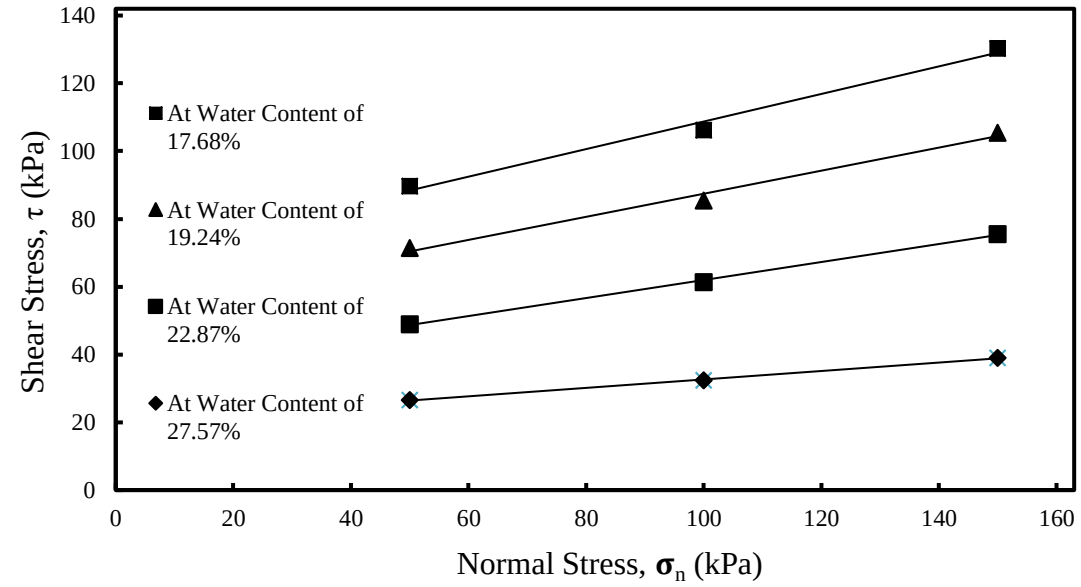
Results and Discussions

Matrix suctions values were calculated experimentally by filter paper method and then shear strength and unconfined compressive strength of unsaturated soil sample were determined using conventional test

Direct Shear Tests

To determine the shear strength of partially saturated soil samples, a series of conventional direct shear test were performed in undrained conditions according to IS: 2720-13. The direct shear tests were done on sample prepared statically at the maximum dry unit weight of 17.13 kN/m^{3}and at OMC 0f 18.06 %. Water content was varied by placing the soil samples on wet or submerged sand bed. Filter paper was positioned in between sand and soil to avoid the direct contact between them. After this samples were air dried (different degree of air drying) to get unsaturated samples. Prepared sample were kept in desiccators to allow equilibration for 7 days period. The soil specimen were kept in shear box and sheared at a rate of 1.25mm/min with applied normal stress of 50 kN/m^2, 100 kN/m^2 and 150 kN/m^2. Total of 16 DST soil specimen ad these 16 samples were categorized into four groups. Some of the soil sample was collected from the interior of failed soil samplefor water content determination. The measured shear strengths of statically compacted fine grained soil dominated with silt content are plotted against the applied normal stress as shown in figure 1.

Figure 1 Shear strength versus the net normal stress at different water content



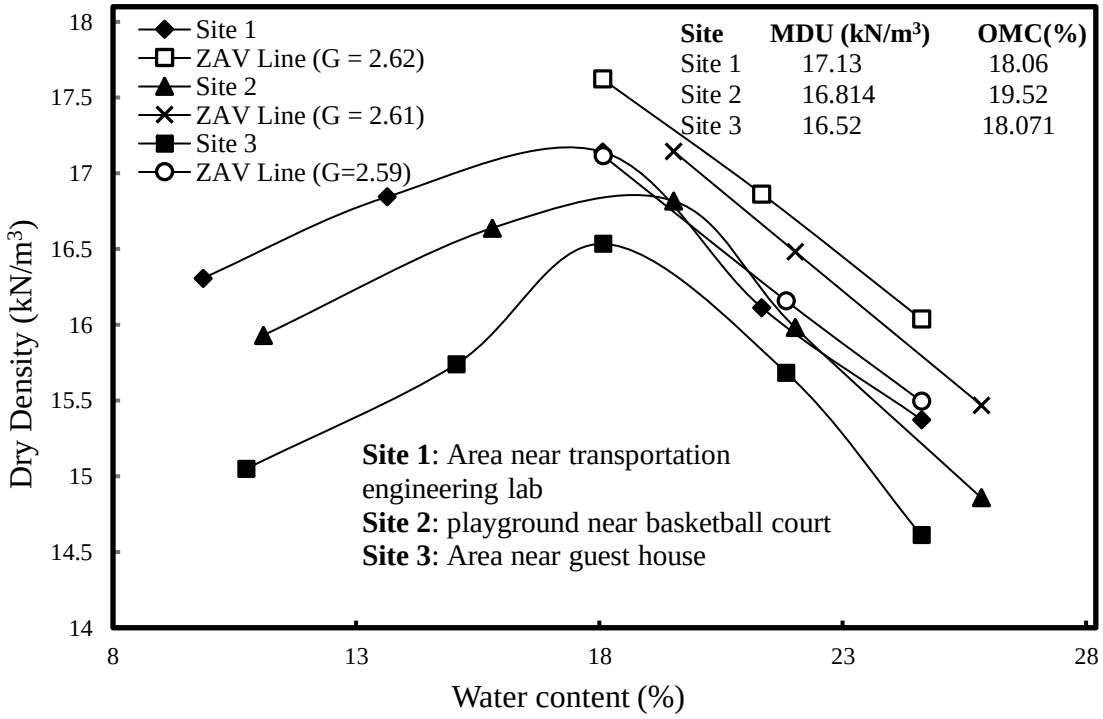


Figure 2 Compaction curves for different soil samples collected

Conclusion

The main aim of this study was to find out the shear strength behavior of partially saturated soils using conventional direct shear and unconfined compression tests. Experimental studies were conducted on soil sample collected from NIT Srinagar. Based on study carried out the following conclusion were made from the results.

1. It was found that as the moisture content of the soil specimen increases the matric suction values decreases. The cost effective technique were used to establish the soil water characteristic curve. Matric suction corresponding to particular moisture content of soil sample were determined from SWCC of the soil. Theoretical model such as Fredlund & Xing (1994) and Van Genutchen (1980) were used in this study to determine SWCC with greater reliability and consistency.
2. The shear strength of unconsolidated undrained soil sample shows direct relation with matric suction. The apparent cohesion and apparent friction values also increases as the matric suction increases.
3. The shear strength envelopes shows non-linear behavior against the matric suction. The gradient of the shear strength envelopes shows inverse variation with matric suction.
4. Although the technique used in this study cannot be used as substitute to the more accurate methods like modified triaxial tests, modified direct shear tests and axis translation technique etc. but being practical, economical and somewhat easier than other methods, this technique is enough efficient to determine the shear strength partially saturated.soil.
5. The unconfined compressive strength of partially saturated soil increases as the matric suction in the soil increases.
6. Experimentally observed results from direct shear test and unconfined compression test were in agreement with the results given by semi-empirical equations.

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