Triaxial Testing Of Soils

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Triaxial Testing of Soils John Wiley & Sons

Suction-controlled triaxial tests have been widely used to characterize unsaturated soils. However, this type of test requires sophisticated and therefore expensive equipment, and is very time consuming because of the low permeability of unsaturated soils. Only a few research universities can afford the equipment, which limits the advancement and implementation of unsaturated soil mechanics. This paper proposes a new triaxial testing system for unsaturated soils based upon minor modifications on the conventional triaxial test apparatus for saturated soils. Instead of controlling suction, high-suction tensiometers are adopted to monitor matric suction variations during constant water content triaxial testing. Also, a photogrammetry-based method is used to measure volume changes of unsaturated soil specimens during triaxial testing. To evaluate the capabilities of the proposed testing system, a series of constant water content triaxial tests were performed on unsaturated soils with different moisture content. Matric suction and volume variations during testing were monitored by the high-suction tensiometers and the photogrammetry-based method, respectively. New methods were also proposed to analyze the test results. Analysis results showed that the proposed system is cost effective and efficient for unsaturated soil characterization.

Consolidated Drained Triaxial Testing of Piedmont Residual Soil ASTM International

Triaxial testing apparatus and procedures for unsaturated soils have become common along with the development of equipment and sensors. Although many drainage conditions are related to the pore-air and pore-water phase, the drained pore-air condition is usually adopted for tests of unsaturated soils. The main reason is that it is difficult to keep the pore-air undrained because the air diffuses easily through a rubber membrane. However, pore-air and pore-water are sometimes not allowed to drain under ground deformation problems. Therefore, undrained conditions in which pore-air and pore-water are not allowed to flow in and out of the soil are achieved in the experiments described herein. First, problems of a conventional triaxial apparatus for unsaturated soils were investigated to produce the undrained conditions. Then, triaxial testing methods under the undrained conditions were developed for overcoming the problems. Finally, the performance of the proposed testing procedure was demonstrated in comparison with results obtained using conventional testing.

Triaxial Testing of Soils and Bituminous Mixtures ASTM International

The paper describes problems encountered in performing consolidated drained triaxial tests on Piedmont residual soil specimens trimmed from both Shelby tube samples and block samples. The micaceous silty soil has steeply dipping layers, planes of weakness, and granular seams. These characteristics complicate trimming and cause specimens to bend during consolidation and shearing. Because some specimens failed at strains of 14% to 20%, the nonuniformities influence the estimation of peak shear strength. To cope with variability, a multistage test on one specimen was compared to behavior measured on three single-stage tests performed on three specimens; all four specimens were trimmed from the same block. Comparative results were inconclusive.

Triaxial Testing of Soils and Bituminous Mixtures Springer Science & Business Media

Triaxial Testing of SoilsJohn Wiley & Sons

Triaxial Testing of Soils and Bituminous Mixtures, Proc. Mtgs. Held San Francisco, 1949 and Atlantic City, 1950 CRC Press

Mechanical properties of frozen soils are invaluable input parameters when designing building foundations or infrastructure in perennial frost areas. Mechanical properties are also important for natural resource development in the north, such as for mining and petroleum-industry-related projects. One of these properties is the shear strength of frozen soil under varying temperatures and loading times. If shear strength is estimated instead of measured, risks for failure or overdesign exist. Therefore, it is important to accurately measure the strength of frozen soils. Two main methods exist for measuring the shear strength of soils: the direct shear test (ASTM D3080) and the triaxial compression test (ASTM D4767, ASTM D7181, and ASTM D2850). Although these tests are routinely used for unfrozen soils, not much published information exists regarding their use for frozen soils. Yet the industry needs this property for planning their operations in cold regions. Therefore, ASTM International Subcommittee D18.19 on Frozen Soils and Rock has started a process of developing new standards for mechanical properties of frozen soils. Of special interest is the dynamic triaxial testing of frozen soils. The purpose of the study reported here was to collect information and practices for the current usage of triaxial testing for frozen soil, under either static or dynamic loading conditions. According to the results of the literature review, researchers use various modified testing systems and sample configurations, and unfortunately they do not always describe them fully. So, standardization of the testing method would be beneficial for creating comparable results between laboratories. The measurement of small strains and deformations in dynamic tests was reported to be challenging. A Split-Hopkinson pressure bar is currently being developed as a means to overcome this problem. Another challenge under investigation is the accuracy of the strain rate control. The synthesized information can be used as a starting point in the development of a standard test method for the dynamic triaxial testing of frozen soils.

Triaxial Testing of Soils and Bituminous Mixtures Springer Science & Business Media
The paper presents the 1986 practice at the Norwegian Geotechnical Institute (NGI) for triaxial testing of soils that are fully saturated in situ. The test procedures for specimen mounting, saturation, consolidation, and static and cyclic shearing are outlined. Sample disturbance, specimen height, end friction, and anisotropic consolidation are discussed at length. Simplified procedures for anisotropic consolidation according to soil types are proposed. Sources of error are mentioned. A new method to measure the initial shear modulus in triaxial soil specimens is described.

Test Procedures for Low-confining Stress, Multistage Triaxial Testing of Compacted Cohesive Soils
The triaxial test has been extensively used to evaluate both saturated and unsaturated soil behaviors. The conventional triaxial test apparatus for saturated soils cannot be used to test unsaturated soils due to difficulties in soil volume and suction measurement. In 1961, a suction-controlled triaxial test apparatus was developed to investigate behavior of unsaturated soils. Since this development, the suction-controlled test has been widely used for unsaturated soil characterization. Most important concepts concerning unsaturated soil mechanics were developed based upon results from suction-controlled tests. However, the suction-controlled triaxial test on unsaturated soils, which is a drained test, is usually laborious, time-consuming, and costly, and may not be justifiable for routine engineering projects. The constant water content (undrained) test has been widely used to investigate saturated soil behaviors. However, for unsaturated soils, due to difficulties in direct, rapid, and reliable suction measurement, the constant water content test was rarely used for unsaturated soil behavior evaluation. In addition, accurate volume change measurement of unsaturated soils was a great challenge for researchers. Recently, the Modified State Surface Approach (MSSA) has been developed to calibrate unsaturated soil behaviors. According to MSSA, both results from suction-controlled and constant water content triaxial tests can be used for constitutive behavior calibration on unsaturated soils. In this study, a new triaxial test system was developed to investigate unsaturated soil behaviors through constant water content triaxial tests. To measure soil suction variation during testing, a new type of high-suction tensiometer was developed based on a commercial miniature pressure transducer. A 15 bar air-entry ceramic disc was used as the filter of the high-suction tensiometer. After saturation and calibration, this new type of high-suction tensiometer could be utilized for matric suction measurement on unsaturated soils with a maximum measurable suction up to 1100 kPa determined via a free evaporation test. To measure the volume change of unsaturated soils during triaxial testing, a photogrammetry-based method was developed by integrating photogrammetry, optical-ray tracing, and least-square estimation techniques. Through two validation tests on a stainless steel cylinder and a saturated sand specimen, the average point and total volume change measurement accuracy were determined to be approximately 0.065 mm and 0.05%, respectively. With this method, the conventional triaxial test apparatus for saturated soils can be used for triaxial testing on unsaturated soils without any modification. In addition to total volume change measurement, the newly developed photogrammetry-based method can also be used to investigate the deformation characteristics of soils during triaxial testing such as full-field deformation, volumetric strain non-uniformity, full-field strain distribution, and shear band evolution process. To evaluate the performance of the new triaxial testing system, a series of constant water content triaxial tests were carried out on unsaturated soils. New methods were proposed to characterize shear strength of the tested unsaturated soils. Also, an example was given to calibrate the constitutive behavior of an unsaturated soil based on results from the constant water content triaxial tests. Analysis results indicated that the proposed triaxial testing system is a cost effective and time efficient alternative to the suction-controlled triaxial testing system. In geotechnical and highway engineering, many projects involve unsaturated soils at shallow depths with low confining stresses (less than 100 kPa). To investigate the behavior of unsaturated soils at low confining stresses, the new triaxial testing system was simplified to a modified unconfined compression testing system. In this simplified system, negative air pressure (i.e., vacuum pressure) was used to provide the low confining stress for the triaxial tests. The high-suction tensiometers were used to monitor soil matrix suction variation during testing. A photogrammetric

method was utilized for deformation measurements of unsaturated soils during triaxial testing. A series of undrained triaxial tests was also carried out to demonstrate the use of the modified unconfined compression testing system for unsaturated soil behavior evaluation under different confining stresses.

Triaxial Testing of Soils and Bituminous Mixtures

The paper first covers common problems with testing equipment and procedures that cause errors in the measured properties of the soil specimen, with emphasis on consolidated-undrained (CU) and consolidated-drained (CD) triaxial tests. These problems are divided into three categories: errors that can be handled via appropriate corrections; errors that must be avoided; and potential errors that must be evaluated when selecting test procedures or interpreting measured data, the most important being the nonuniform stresses and strains caused by frictional end caps. The paper then assesses the use of triaxial testing in practice to predict undrained stability and deformations for saturated cohesive deposits. Based on considerations of strain rate effects, soil anisotropy, disturbance from tube sampling, and results from case histories of failures, the authors make four recommendations. 1. UU compression tests should not be used as the principal means of estimating in situ undrained strengths because the values can be either significantly too high or too low. 2. CIU compression tests have little value because the measured undrained strength will be unsafe for stability analyses, and the stress-strain data do not simulate in situ behavior. 3. Therefore, more reliance should be placed on CKoU compression and extension tests, which would be aided by the availability of more reliable and less expensive automated "stress path" triaxial cells. 4. Oedometer tests should always be conducted to ascertain the stress history of the deposit.

State-of-the-Art Paper

This paper describes a test method to measure the shear strength of unsaturated soils using standard triaxial equipment with minor, low-cost modifications. The method is based on using the axis translation technique in a standard triaxial testing apparatus with a base pedestal slightly modified to accommodate a high-air-entry ceramic disk. The testing apparatus and procedure are described. The aim of the proposed test setup was to limit the modifications of the standard triaxial setup within a reasonable budget to make the method accessible and attractive to researchers and practitioners that may otherwise not be able to afford the testing devices commonly used in the field of unsaturated soil mechanics. Thus, the paper discusses the effectiveness of the proposed test method, and also discusses the potential limitations that may exist due to some of the simplifications used in this methodology. The proposed methodology was used to evaluate the shear strength of residual soils at the Auburn National Geotechnical Experimentation Site. The shear strength parameters obtained for the Auburn unsaturated soils were compared to previous tests conducted in similar soils and proved to be reasonably accurate.

A Multistage Triaxial Test for Unsaturated Soils

Specimen preparation, Triaxial test (soils), Soil strength tests, Consolidation test (soils), Soils, Test equipment, Shear testing, Mathematical calculations, Soil testing, Test specimens, Testing conditions, Soil-testing equipment, Compression testing, Construction

Geosynthetics in Civil and Environmental Engineering

This paper presents an experimental methodology for using multistage, drained triaxial tests on compacted soils under unsaturated conditions to estimate soil-specific relationships between mean effective stress and matric suction. Tests were performed by applying a matric suction to a soil specimen in a triaxial cell using the axis translation technique with back-pressure, then shearing the specimen under drained conditions until reaching stress-path tangency. The specimen was then unloaded, a new suction was applied, and the shearing process was repeated. The points of maximum principal stress difference for the unsaturated specimen were plotted versus mean effective stress, defined using the degree of saturation as the effective stress parameter, and they were found to correspond well with the critical state line defined from triaxial tests on saturated specimens. The suction stress for the compacted soil tested in this study was observed to increase nonlinearly with suction, tending toward a constant value with increasing suction. Although there are potential changes in soil structure in the specimen during loading, unloading, and reloading, the results indicate that the multistage testing method may be useful for estimating soil-specific effective stress parameters for compacted soils in unsaturated conditions. Furthermore, the fact that differences in the soil-water retention curve of soil specimens subjected to different net confining pressures were observed for the soil tested in this study emphasizes the importance of using soil-specific tests to validate predictive relationships between suction stress and matric suction.

Geosynthetics in Civil and Environmental Engineering presents contributions from the 4th Asian Regional Conference on Geosynthetics held in Shanghai, China. The book covers a broad range of topics, such as: fundamental principles and properties of geosynthetics, testing and standards, reinforcement, soil improvement and ground improvement, filter and drainage, landfill engineering, geosystem, transport, geosynthetics-pile support system and geocell, hydraulic application, and ecological techniques. Special case studies as well as selected government-sponsored projects such as the Three Gorges Dam, Qinghai-Tibet Railway, and Changi Land reclamation project are also discussed. The book will be an invaluable reference in this field.

Triaxial testing of soils and bituminous mixtures

The use of the triaxial test to characterize the strength of soils for civil engineering applications is widespread. These tests are typically conducted with confining stresses in excess of 5 psi. To characterize the strength of a soil located in the upper layers of the subgrade of an aggregate surfaced road it is necessary to conduct triaxial tests with low confining stresses (5 psi or less). The development of a method for conducting multistage, consolidated undrained (CU) tests at low confining stresses (0.5 to 5.0 psi), with back pressure saturation, is presented. Aspects of the test procedure that require special attention are described and recommendations are made including: 1. Compaction of the sample in an atmosphere of carbon dioxide reduces the time and pressure required to complete back pressure saturation. 2. Seepage force related pore pressures develop during sample flooding. Zeroing of the effective stress transducer should be completed prior to sample flooding so that it is certain that zero effective stress conditions are present. 3. Back pressure saturation is simplified by the use of a slave regulator (air loaded pressure regulator) that maintains a nearly constant pressure differential between the cell pressure and the back pressure. 4. The stress path method of interpretation is an essential part of multistage triaxial testing. This method simplifies the decision of when to stop each shear stage and the determination of shear strength parameters. 5. The use of a computer data acquisition system that processes data in real time and visually presents test progress simplifies the completion of multistage triaxial tests.

The Measurement of Soil Properties in the Triaxial Test

A triaxial testing procedure is presented for measuring the increase in shear strength resulting from soil suction in an unsaturated soil. Necessary modifications on a conventional triaxial cell are described. A simple graphical method is presented to interpret the test data in accordance with the shear strength equation for unsaturated soils.

A New Technique in Triaxial Testing of Soils

Significant advancements in the experimental analysis of soils and shales have been achieved during the last few decades. Outstanding progress in the field has led to the theoretical development of geomechanical theories and important engineering applications. This book provides the reader with an overview of recent advances in a variety of advanced experimental techniques and results for the analysis of the behaviour of geomaterials under multiphysical testing conditions. Modern trends in experimental geomechanics for soils and shales are discussed, including testing materials in variably saturated conditions, non-isothermal experiments, micro-scale investigations and image analysis techniques. Six theme papers from leading researchers in experimental geomechanics are also included. This book is intended for postgraduate students, researchers and practitioners in fields where multiphysical testing of soils and shales plays a fundamental role, such as unsaturated soil and rock mechanics, petroleum engineering, nuclear waste storage engineering, unconventional energy resources and CO2 geological sequestration.

Laboratory Shear Testing of Soils

"Although the triaxial compression test is presently the most widely used procedure for determining strength and stress-deformation properties of soils, there have been no books published on triaxial testing since the 1962 second edition of the landmark work The Measurement of Soil Properties in the Triaxial Test by Bishop and Henkel. It is apparent there is a need to document advances made in triaxial testing since publication of Bishop and Henkel's book and to examine the current state of the art in a forum devoted solely to triaxial testing. Because of increasing versatility brought about by recent developments in testing techniques and equipment, it is also important that the geotechnical profession be provided with an up-to-date awareness of potential uses for the triaxial test."--Overview.

Triaxial Testing of Soils and Bituminous Mixtures

Triaxial Testing of Soils explains how to carry out triaxial tests to demonstrate the effects of soil behaviour on engineering designs. An authoritative and comprehensive manual, it reflects current best practice and instrumentation.References are made throughout to easily accessible articles in the literature and the books focus is on how to obtain high quality experimental results.

Triaxial Testing of Soils

This is a collection of articles from the Asian conference UNSAT-ASIA 2000, covering topics such as: historical developments; numerical modelling; suction measurement techniques; permeability and flow; mass transport; and engineering applications.

A Cost Effective Triaxial Test Method for Unsaturated Soils

Soil-testing equipment, Test equipment, Soils, Specimen preparation, Reports, Soil testing, Mechanical testing, Soil strength tests, Construction, Compression testing, Testing conditions, Mathematical calculations, Triaxial test (soils), Shear testing, Vane test

Triaxial Testing of Soils and Bituminous Mixtures

Specimens of sedimented kaolinite were subjected to consolidated-undrained triaxial compression by means of a new electropneumatic control system that will apply any desired loading path in the axisymmetric stress space or any desired deformation path. Specimens were tested under ramp loading, ramp deformation and combined ramp loading?ramp deformation with both constant cell pressure and constant first invariant of the applied stress tensor. To determine the entire stress-strain-pore pressure relationship, it was necessary to perform the combined load rate-deformation rate test. It was found that while a unique principal stress difference-major principal strain relationship exists, a unique pore pressure-major principal strain relationship does not exist.