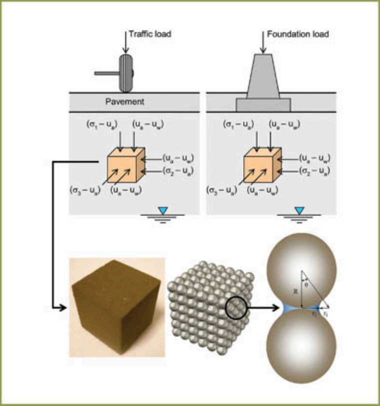
Experimental and Applied Modeling of Unsaturated Soils



Geotechnical Special Publication No. 202

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ASCE
G-I GEO-INSTITUTE

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Experimental and Applied Modeling of Unsaturated Soils

PROCEEDINGS OF SESSIONS OF GEOSHANGHAI 2010

June 3–5, 2010
Shanghai, China

HOSTED BY
Tongji University
Shanghai Society of Civil Engineering, China
Chinese Institution of Soil Mechanics and Geotechnical Engineering, China

IN COOPERATION WITH
Alaska University Transportation Center, USA
ASCE Geo-Institute, USA
Deep Foundation Institute, USA
East China Architectural Design & Research Institute Company, China
Georgia Institute of Technology, USA
Nagoya Institute of Technology, Japan
Transportation Research Board (TRB), USA
The University of Newcastle, Australia
The University of Illinois at Urbana-Champaign, USA
The University of Kansas, USA
The University of Tennessee, USA
Vienna University of Natural Resources and Applied Life Sciences, Austria

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Published by the American Society of Civil Engineers

Library of Congress Cataloging-in-Publication Data

GeoShanghai International Conference (2010)
Experimental and applied modeling of unsaturated soils : proceedings of the GeoShanghai 2010 International Conference, June 3-5, 2010, Shanghai, China / edited by Laureano R. Hoyos, Xiong Zhang, Anand J. Puppala.
p. cm. -- (Geotechnical special publication ; 202)
Includes bibliographical references and index.
ISBN 978-0-7844-1103-2
1. Soil mechanics--Simulation methods--Congresses. 2. Zone of aeration--Simulation methods--Congresses. 3. Soil moisture--Measurement--Congresses. I. Hoyos, Laureano R., 1972- II. Zhang, Xiong, 1971- III. Puppala, Anand J. IV. Title.

TA710.A1G368 2010b
624.1'5136011--dc22 2010012086

American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia, 20191-4400

www.pubs.asce.org

ISBN 978-0-7844-1103-2
Manufactured in the United States of America.

Preface

Geotechnical and civil engineers all over the world continue to face problems with a wide range of geosystems involving materials that remain under partially saturated conditions throughout the year. The lack of education and training among engineering graduates and practitioners to properly deal with unsaturated soil conditions has resulted in faulty or excessively conservative designs, frequent construction delays, and deficient long-term performance of built infrastructure. Over the last few decades, however, the discipline of unsaturated soil mechanics has begun to receive increasing attention worldwide, providing better explanations for soil behavioral patterns than conventional saturated soil mechanics.

This Geotechnical Special Publication on *Experimental and Applied Modeling of Unsaturated Soils* comprises a total of 28 peer-reviewed papers selected for presentation at the Unsaturated Soils sessions of the *GeoShanghai 2010* conference held in Shanghai, China, June 3-5, 2010, and hosted by Tongji University. The sessions were organized and sponsored by the Committee on Unsaturated Soils of the Geo-Institute of the ASCE, with co-sponsorship of the Technical Committee No. 6 (TC6) on Unsaturated Soils of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE).

The current GSP is the latest in a successful series of special publications published by the Geo-Institute documenting the most recent advances in the unsaturated soil mechanics discipline, starting with GSP No. 68 on *Unsaturated Soil Engineering Practice* from the first Geo-Institute Conference in Logan, Utah, July 15-19, 1997. The papers included in this GSP have been divided into two broad categories. Part I on *General Characterization and Constitutive Behavior* is devoted to some of the most recent advances in characterization and prediction of engineering properties, mechanical response and constitutive behavior of unsaturated soil materials, included compacted, collapsible and expansive soils. Part II on *Applied Modeling and Analysis* is devoted to the most recent advances in the state of the art concerning both laboratory and field measurements of unsaturated soil properties and phenomena for particular practical applications, including centrifuge testing and ground-penetrating radar (GPR). Papers dealing with unsaturated slope stability analyses and foundation heave predictions as affected by environmental variables such as rainfall, freeze-thaw, vegetation and water migration in the vadose zone are also included in this second part.

Each of the papers included in this publication received at least two positive peer reviews. The Editors would like to express their most sincere appreciation to all of the anonymous reviewers for their diligent work, with special thanks to Ms. Claudia Velosa, doctoral candidate at the University of Texas at Arlington, for her valuable assistance in the final editing of the papers, and to Mrs. Donna Dickert of the ASCE for patiently coordinating the logistics of the publication process.

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Part II: Applied Modeling and Analyses

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Retention Properties and Compressibility of a Compacted Soil

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ABSTRACT: Soil-water retention properties and compressibility are closely related to the stability of geotechnical engineering structures made of compacted soils. In the present study, the water retention curve of a compacted soil from Northern France was characterized using either suction control method or suction measurement. The results obtained showed a good correspondence between the two methods. Then, these two experimental methods were used in oedometer compression test to highlight the factors influencing the compression properties, especially in terms of changes in compression index as a function of initial suction and initial structure (i.e. density). In the case of low density (1.1 Mg/m^3), the results evidenced different zones for the variations of compression index, separated by a stress threshold. Compression index did not change significantly when suction values were relatively high and the applied vertical stresses were lower than the identified threshold stress.

INTRODUCTION

The soil compressibility is highly variable both in time and space because it depends on soil type (texture), soil structure (porosity) and soil moisture (suction). To ensure the stability of structures involving compacted soils, it is essential to understand the water retention property and volume change behaviour of the soils under the combined mechanical and hydraulic effects. Most of results have been obtained for soils with very high dry bulk densities, and showed that compression index decreases with increasing suction. But for some loose soils such as compacted soils, some authors have found that it decreases with suction (Zhang et al. 1997, Défossez et al. 2003) while others have observed that soil suction has an insignificant effect (Larson et al. 1980, Smith et al. 1997, Arvidsson and Keller 2004, Imhoff et al. 2004, Mosaddeghi et al. 2006). In the present work, the water retention properties of a compacted soil taken from Northern France were characterized using either suction control method or suction measurement. Osmotic suction control method was used for the desiccation path and suction measurement using high capacity tensiometer was applied for the humidification path. Then, these two experimental methods were used in oedometer compression test to investigate the suction effect on the compression properties.

MATERIALS

For this study, a compacted loamy soil (17.3% clay, 77.7% silt, 5% sand) from a site at Mons in Northern France was used. The soil has a liquid limit of 29%, a plasticity index of 6 and a solid density of 2.7 Mg/m^3. Air-dried soil was passed through 2 mm sieve. The water content of the soil powder is 2%.

TESTING EQUIPMENT AND PROCEDURE

Suction Control Method

The osmotic technique for suction control testing is based on the use of a cellulose semi-permeable membrane and an aqueous solution of organic polyethylene glycol (PEG) molecules. When the soil is separated from the PEG solution by the membrane, water can cross the membrane whereas the PEG molecules in solution cannot due to their large size. The water stops flowing once equilibrium state is reached; there is thus the same suction in the PEG solution and the soil. This suction is known from the PEG calibration curve. According to Delage et al. (1998) and Delage and Cui (2000), there is a unique relationship between PEG concentration, C (g PEG/g water) and suction, s (MPa), independent of the molecular weight of the PEG.

Oedometer compression tests were conducted with suction state controlled using the osmotic technique to study the compression index. A standard oedometer was adapted to the osmotic technique, allowing compression tests at controlled suction. Figure 1 shows the osmotic-based oedometer employed. The cell base was grooved to homogenize the distribution of the PEG solution; a fine sieve was placed over the grooves to protect the semi-permeable membrane placed between the sieve and the soil sample. A closed circuit activated by a peristaltic pump was designed to circulate the PEG solution. A one-litre bottle was used to ensure a quasi-constant concentration in spite of water exchanges with the soil sample. A capillary tube placed on the sealed bottle allowed monitoring water exchanges between the PEG solution and the soil sample. The bottle was placed in a thermostatic water bath at 20±0.5°C to avoid any temperature effects on the water exchange measurements.

In addition, the entire system was installed in an air-conditioned room (20±1°C). In order to quantify the change of water volume due to temperature and evaporation, a second bottle full of PEG solution with a capillary tube was placed in the water bath.

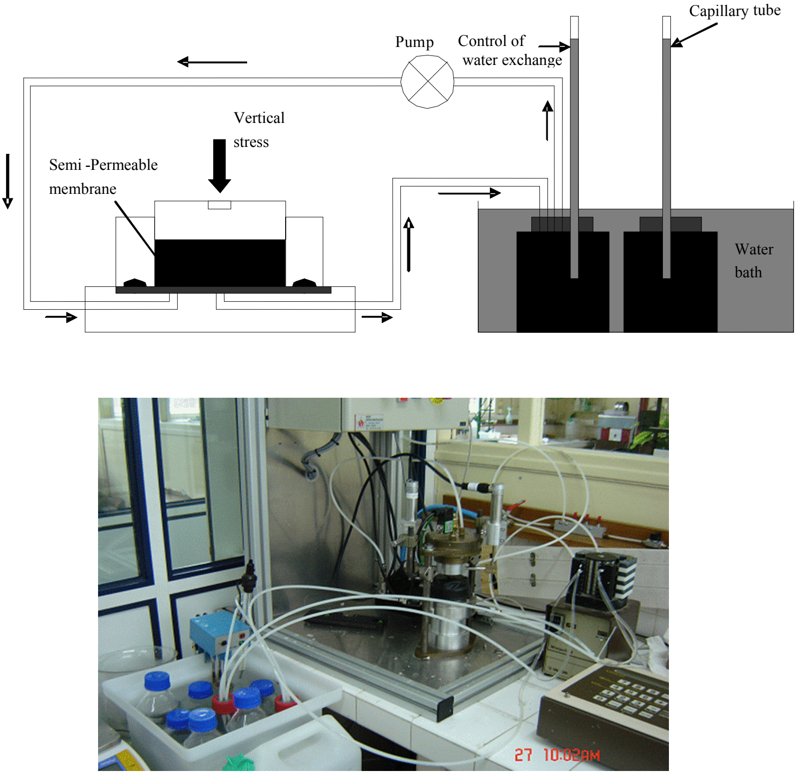

Figure 1. Schematic of osmotic oedometer and actual picture

Series I: For each sample preparation, 103.62 ± 0.05 g dry powder was used. The soil powder was humidified by pulverization to reach 12.5% water content; the sample was prepared by compaction in the oedometer cell to reach dimensions of 70 mm in diameter and 24 mm high, with a dry bulk density of 1.1 Mg m^{-3}. The initial suction of the compacted sample before compression test was about 200 kPa, estimated by the tensiometer considered in the other experimental method: suction measurement. Series II: Test samples were prepared at different initial water content w_i = 12.5, 13, 16 and 25% which supply the initial suctions near to 200, 100, 50 and 10 kPa separately.

For the series I, the six compression tests were performed at different suctions: 0, 10, 50, 100, 180 and 200 kPa, each test having been started with a suction application process under zero vertical stress. The suction was applied either by circulating PEG solution of the desired concentration or pure water (for zero suction). Equilibrium was indicated by stabilization of the solution level in the capillary tube,