

Geotechnical Frontiers 2025

GSP 366

Geotechnics of Natural Hazards

Selected Papers from Geotechnical Frontiers 2025
Louisville, Kentucky • March 2–5, 2025

Edited by
Melissa S. Beauregard, Ph.D., P.E., ENV SP
Aaron S. Budge, Ph.D., P.E., BC.GE

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GEOTECHNICS OF NATURAL HAZARDS

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EDITED BY
Melissa S. Beauregard, Ph.D., P.E., ENV SP
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Preface

This is the fourth volume of six Geotechnical Special Publications (GSPs) containing papers from the Geotechnical Frontiers 2025 Conference held in Louisville, Kentucky on March 2-5, 2025. Geotechnical Frontiers occurs every six years and is the merging of the Geosynthetics Conference and the annual Geo-Congress replacing both events in 2025. This popular event is where the geotechnical, civil and geo-professional communities unite to share developments in geotechnical engineering and technologies. The four-day event featured more than 200 exhibits, plus a comprehensive program of short courses, panel discussions, round table discussions, technical paper lectures and posters presented by top industry experts as well as the industry's most influential plenary speakers. Geotechnical Frontiers 2025 was organized by the Advanced Textile Association's Geosynthetic Materials Association and the American Society of Civil Engineer's Geo-Institute. The congress was attended by a wide range of geo-professionals including engineers, contractors, academicians, equipment manufacturers, geo-technologists, researchers, and service, material and tooling suppliers.

This publication culminates two years of effort by the technical planning committee whose focus has been to continue the success of the previous meetings in the Geotechnical Frontiers conference series. Many individuals are responsible for the content of this volume, all of whom served in the efforts to maintain the standard set by previous proceedings. An international call for papers and a rigorous peer review process yielded nearly 300 accepted technical papers that were presented in 37 technical and special sessions, in addition to invited keynote presentations. Papers were reviewed in accordance with ASCE GSP standards. Accordingly, each paper was subjected to technical review by two or more independent peer reviewers. Publication requires concurrence by at least two peer reviewers.

The Editors would like to express their appreciation for having been provided the opportunity to be a part of this Congress' organization along with their sincere thanks to the numerous session chairs and reviewers. We hope that these proceedings will be of use to the geotechnical engineering community for many years to come.

The Editors,

Melissa S. Beauregard, Ph.D., PE, ENV-SP, M.ASCE, U.S. Army Corps of Engineers

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Effect of Pore Fluid Salinity on Isotropic Compressibility, Vertical Permeability, and Triaxial Stress–Strain Behavior of Kaolinite

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ABSTRACT

Reported rates of sea-level rise in the Mid-Atlantic region of the United States, which are twice the global average, may affect the hydro-mechanical behavior and engineering properties of soils in coastal floodplain areas or subterranean coastal aquifers. Changes in these environmental conditions can have a “loading” effect on soils and may impact the engineering behavior and stability of both naturally occurring and manmade coastal infrastructure. In particular, a given temporary or permanent rise in sea level causes saltwater intrusion into both saturated and unsaturated soils, consequently affecting the pore fluid composition of these soils. The change in hydration force caused by the dissolution of charged solute, e.g., natural seawater salt, into fresh pore water can produce osmotic suction and change the intermolecular forces between soil particles. This microscale effect can consequently affect the macroscale response of the soil. To develop a robust understanding of the behavior of natural soils, which are inherently varied and complex in nature, it is useful first to examine the behavior of simpler soils in isolation, such as the behavior of a relatively uniform clay mineral. Consequently, this study investigates the influence of changing pore fluid conditions on the compressibility, permeability, and stress–strain behavior of a commercially available kaolinite by performing isotropic consolidation, constant-head permeability, and consolidated undrained triaxial compression tests. The results show that by changing the pore fluid from distilled water to a 0.6 mol/L NaCl solution, the compression ratio was reduced by about 27%, the permeability was reduced by 35%, the undrained shear strength increased by 7%, and the critical state line slope remained almost constant.

INTRODUCTION

Sea level rise is one of the main indirect effects of climate change in coastal regions. Satellite radar measurements show that the global average sea level rose by about 0.2 m from 1990 to 2010 (Haj-Amor and Bouri 2020). The field data of instrumented sites near the sea along the eastern coast of the USA indicate that the pore fluid composition of soils varies relative to their proximity to the source of salinity, i.e., seawater (e.g., Baker et al. 2024). As the sea level rises, it can result in significant changes in the pore fluid composition of soils that exist in our natural environments.

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Volume change behavior (e.g., Yoosefi et al. 2024), hydraulic conductivity and water retention (e.g., Tang et al. 2020, Jebeli et al. 2024), and shear strength (e.g., Geng et al. 2022) of clays are some examples of geotechnical properties that can be affected by the dissolution of charged solutes into pore water. Such physicochemical changes can affect soil with more than 10% clay content (Mitchell and Soga 2005). Bjerrum (1954) highlighted the significant impact of salt concentration on the shear strength of clay soils, noting that a reduction in salt concentration due to leaching in marine clays can lead to a corresponding decrease in shear strength. Past research indicates that increasing the salinity of pore water tends to increase the residual shear strength of montmorillonite (e.g., Maio and Fenellif 1994); on the other hand, exposure to NaCl (Maio and Fenellif 1994) or $CaCl_2$ (Anson and Hawkins 1998) solutions did not affect the residual shear strength of kaolinite. In certain instances, a decrease or marginal increase in the residual shear strength of kaolinite has been documented, depending on the level of salinity (Moore 1991). Most studies evaluating the pore fluid salinity on the shear strength of clay soils are primarily focused on assessing the residual shear strength using ring shear or direct shear tests (e.g., Maio and Fenellif 1994). One of the limited studies that investigated the effect of salinity on the shear strength of clay soils using the triaxial compression test was conducted by Gen et al. (2022). Moreover, the volume change behavior of clay can be affected by its electrolyte content (e.g., Bolt 1956), and research into the impact of salinity on kaolinite compressibility has been extensively conducted in the literature, primarily through the utilization of the 1D consolidation test (e.g., Chen et al. 2000, Yoosefi et al. 2024). However, the lack of attention given to assessing the influence of pore fluid properties on the stress-strain response of clays is evident in the validation process of developed chemomechanical constitutive models for clay soils, which typically rely on the results of 1D consolidation tests (e.g., Musso et al. 2022). The hydraulic conductivity of clays can also be affected by pore fluid composition (e.g., Tang et al. 2020), and consequently, it can affect the consolidation rate and pore water pressure development under undrained conditions.

Understanding the complex behavior of natural soils benefits from studying simpler soils first, like examining the behavior of relatively uniform (“pure”) clay minerals. Given the lack of experimental results that investigate the effect of pore fluid salinity on the stress-strain behavior of kaolinite under triaxial conditions and only considering the compressibility behavior under isotropic conditions, this study aimed to evaluate the effect of osmotic suction (controlled by the amount of salt content of the pore fluid) on the compressibility, permeability, and stress-strain behavior of a commercially available kaolinite by performing isotropic consolidation, constant-head permeability, and consolidated undrained triaxial compression tests.

EXPERIMENTAL STUDIES

Materials and Sample Preparation

A commercially available kaolinite (denoted as *K* in this paper) was used in this study. The basic physical properties of the tested soil are also presented in Table 1. The X-ray diffraction (XRD) test results for the kaolinite used in this study are presented by Yoosefi et al. (2024), and the results showed that the kaolinite is predominantly composed of kaolinite (K) with the compound name of Aluminum Silicate Hydroxide ($Al_2 Si_2 O_5 (OH)_4$).

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