# Geo-Congress 2019

GSP 310

## Geotechnical Materials, Modeling, and Testing





Papers from Sessions of the
Eighth International Conference on
Case Histories in Geotechnical Engineering

Philadelphia, Pennsylvania
March 24–27, 2019

EDITED BY Christopher L. Meehan, Ph.D., P.E.
Sanjeev Kumar, Ph.D., P.E.
Miguel A. Pando, Ph.D., P.Eng.
Joseph T. Coe, Ph.D.

ASCE

G-I GEO-INSTITUTE
ASCE

GEOTECHNICAL SPECIAL PUBLICATION NO. 310

# GEO-CONGRESS 2019

## *GEOTECHNICAL MATERIALS, MODELING, AND TESTING*

SELECTED PAPERS FROM SESSIONS OF THE EIGHTH INTERNATIONAL CONFERENCE ON CASE HISTORIES IN GEOTECHNICAL ENGINEERING

March 24–27, 2019
Philadelphia, Pennsylvania

SPONSORED BY
The Geo-Institute of the
American Society of Civil Engineers

EDITED BY
Christopher L. Meehan, Ph.D., P.E.
Sanjeev Kumar, Ph.D., P.E.
Miguel A. Pando, Ph.D., P.Eng.
Joseph T. Coe, Ph.D.

**Published by the American Society of Civil Engineers**

Published by American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia, 20191-4382
www.asce.org/publications | ascelibrary.org

Any statements expressed in these materials are those of the individual authors and do not necessarily represent the views of ASCE, which takes no responsibility for any statement made herein. No reference made in this publication to any specific method, product, process, or service constitutes or implies an endorsement, recommendation, or warranty thereof by ASCE. The materials are for general information only and do not represent a standard of ASCE, nor are they intended as a reference in purchase specifications, contracts, regulations, statutes, or any other legal document. ASCE makes no representation or warranty of any kind, whether express or implied, concerning the accuracy, completeness, suitability, or utility of any information, apparatus, product, or process discussed in this publication, and assumes no liability therefor. The information contained in these materials should not be used without first securing competent advice with respect to its suitability for any general or specific application. Anyone utilizing such information assumes all liability arising from such use, including but not limited to infringement of any patent or patents.

ASCE and American Society of Civil Engineers—Registered in U.S. Patent and Trademark Office.

*Photocopies and permissions*. Permission to photocopy or reproduce material from ASCE publications can be requested by sending an e-mail to permissions@asce.org or by locating a title in ASCE's Civil Engineering Database (http://cedb.asce.org) or ASCE Library (http://ascelibrary.org) and using the "Permissions" link.

***Errata:*** **Errata, if any, can be found at https://doi.org/10.1061/9780784482124**

Copyright © 2019 by the American Society of Civil Engineers.
All Rights Reserved.
ISBN 978-0-7844-8212-4 (PDF)
Manufactured in the United States of America.

# Preface

From the early days of modern geotechnical engineering, sharing field experience on the performance of geostructures in the form of case histories has driven the advancement of knowledge for the geotechnical profession. Starting in 1984, Professor Shamsher Prakash formalized this tradition, organizing the First International Conference on Case Histories in Geotechnical Engineering. This conference brought together over 190 engineers from 38 countries to share their experiences, learn from each other, and advance the profession. By 2013, the Seventh conference in this series had grown to nearly 320 engineers attending from 53 countries spanning the globe, culminating in symposia to honor the legacy of the late Ralph B. Peck and to honor Clyde N. Baker Jr. But the essence of the conference had not changed: to advance our profession through lessons learned from case histories and shared engineering judgment.

Recognizing the significant role that case histories play in the geotechnical engineering profession, the American Society of Civil Engineers (ASCE) has decided to continue the tradition of this long-standing conference series by merging this conference into its annual Geo-Institute Congress. The result is Geo-Congress 2019: The Eighth International Conference on Case Histories in Geotechnical Engineering, which was held in Philadelphia, Pennsylvania on March 24-27, 2019.

The following pages comprise the sixth volume of ten Geotechnical Special Publications (GSPs) containing papers from Geo-Congress 2019: The Eighth International Conference on Case Histories in Geotechnical Engineering. This conference featured experiences and observations from numerous geoengineering projects and case histories, including recent "MegaProjects." Presented topics are organized into the following conference proceeding volumes:

Volume 1: Embankments, Dams, and Slopes
Volume 2: Earth Retaining Structures and Geosynthetics
Volume 3: Foundations
Volume 4: Earthquake Engineering and Soil Dynamics
Volume 5: Soil Improvement
Volume 6: Geotechnical Materials, Modeling, and Testing
Volume 7: Engineering Geology, Site Characterization, and Geophysics
Volume 8: Geoenvironmental Engineering and Sustainability
Volume 9: Soil Erosion, Underground Engineering, and Risk Assessment
Volume 10: Data, Software, Education, and a Tribute to Ralph Peck

Many individuals are responsible for the content of these published works, all of whom contributed to maintaining the high standards that are set for ASCE's GSPs. An international call for papers and rigorous peer review process yielded 403 accepted

© ASCE

technical papers, that were presented in 36 podium sessions and numerous poster sessions, in addition to the keynote award presentations, Geo-PITs (Powerful, Informative Talks), and panel sessions. Papers in these volumes were reviewed in accordance with ASCE's GSP standards, with each paper receiving two or more independent, technical peer reviews. Publication in these Proceedings required concurrence by at least two peer reviewers.

This publication series culminates two years of effort by the conference organizing committee whose focus has been to build upon and enhance the success of the past International Conferences on Case Histories in Geotechnical Engineering. On behalf of the conference organizers and the ASCE Geo-Institute, we wish to express our gratitude to all of the session chairs and reviewers for their diligent efforts to make these Proceedings a reality. We also wish to extend our thanks to Geo-Institute staff, whose tireless efforts working with authors, session chairs, and members of the conference organizing committee were instrumental in the conference planning process. Finally, we would like to thank the authors for their contributions to the Proceedings. The papers that have been submitted by our colleagues do a great service to the legacy of the previous "Case Histories in Geotechnical Engineering" conferences, and are of great value to the geotechnical engineering profession.

**The Editors,**

Christopher L. Meehan, Ph.D., P.E., F.ASCE, University of Delaware
Sanjeev Kumar, Ph.D., P.E., F.ASCE, Southern Illinois University Carbondale
Miguel A. Pando, Ph.D., P.Eng., M.ASCE, University of North Carolina Charlotte
Joseph T. Coe, Ph.D., M.ASCE, Temple University

© ASCE

# Acknowledgments

Thanks are due to the authors, primary reviewers, session chairs, and program committee, without whom this publication would not be possible.

**2019 Geo-Congress Conference Organizing Committee**

Conference Co-chair: Scott M. Olson, Ph.D., P.E., M.ASCE
Conference Co-chair: Allen Cadden, P.E., D.GE, F.ASCE
Technical Program Co-chair: Sanjeev Kumar, Ph.D., P.E., M.ASCE
Technical Program Co-chair: Jared Green, P.E., M.ASCE
Technical Program Co-chair: Christopher L. Meehan, Ph.D., P.E., F.ASCE
Proceedings Editor: Christopher L. Meehan, Ph.D., P.E., F.ASCE
Proceedings Editor: Sanjeev Kumar, Ph.D., P.E., M.ASCE
Proceedings Editor: Joseph Thomas Coe, Jr., Ph.D., A.M.ASCE
Proceedings Editor: Miguel A. Pando, Ph.D., P.Eng., A.M.ASCE
Student Activities Chair: Stacey Kulesza, Ph.D., P.E., M.ASCE
Sponsorships and Exhibits Co-chair: George Koerner, Ph.D., P.E., M.ASCE
Sponsorships and Exhibits Co-chair: Archie Filshill, P.E., M.ASCE
Sponsorships and Exhibits Co-chair: Ben Dutton, P.E.
Sponsorships and Exhibits Co-chair: John Grillo, P.E., M.ASCE
Local Liaisons: James A. McKelvey, P.E., D.GE, F.ASCE; Michael Fritzges, P.E., M.ASCE; Conrad Cho, P.E., LEED AP

**2019 Geo-Congress Sessions and Session Chairs**

Reza S. Ashtiani, Ph.D.
Robert C. Bachus, Ph.D., P.E., D.GE, M.ASCE
Eric S. Backlund, P.E., M.ASCE
Paola Bandini, Ph.D., P.E., M.ASCE
Tuğçe Başer, Ph.D., A.M.ASCE
Melissa S. Beauregard, Ph.D.
Michelle L. Bernhardt, Ph.D., A.M.ASCE
Bernardo A. Castellanos, Ph.D., A.M.ASCE
J. Tanner Blackburn, Ph.D., P.E., M.ASCE
Jan Cermak, Ph.D., P.E., M.ASCE
Deepankar Choudhury, Ph.D., M.ASCE
Maria Chrysochoou, Ph.D.
Jose Luiz Machado Clemente, Ph.D., P.E., D.GE, F.ASCE
Joseph Thomas Coe, Jr., Ph.D., EIT, A.M.ASCE
Shideh Dashti, Ph.D., A.M.ASCE
Haitham M. Dawood, Ph.D., P.E., A.M.ASCE
Ahmed Faheem, Ph.D., A.M.ASCE

© ASCE

Michael B. Fritzges, P.E., M.ASCE
Patricia M. Gallagher, Ph.D., P.E.
Sarah L. Gassman, Ph.D., P.E., M.ASCE
Majid Ghayoomi, Ph.D., A.M.ASCE
Ehsan Ghazanfari, Ph.D., P.E., M.ASCE
Michael G. Gomez, Ph.D., A.M.ASCE
Jared M. Green, P.E., A.M.ASCE
*Garry* H. *Gregory*, Ph.D., P.E., *D.GE,* M.ASCE
Jonathan F. Hubler, Ph.D., A.M.ASCE
Marco Isola, Ph.D., P.E., M.ASCE
James Kaklamanos, Ph.D., A.M.ASCE
Victor N. Kaliakin, Ph.D., M.ASCE
Prabir Kumar Kolay, Ph.D., P.E., M.ASCE
Joseph F. Labuz, Ph.D., P.E., F.ASCE
Ben A. Leshchinsky, Ph.D., P.E., A.M.ASCE
Bret N. Lingwall, Ph.D., P.E., M.ASCE
Barbara Luke, Ph.D., P.E., D.GE, F.ASCE
Kalehiwot Nega Manahiloh, Ph.D., P.E., M.ASCE
John S. McCartney, Ph.D., P.E., M.ASCE
Michael P. McGuire, Ph.D., P.E., M.ASCE
James A. McKelvey, III, P.E., D.GE, F.ASCE
Christopher L. Meehan, Ph.D., P.E., F.ASCE
Brian C. Metcalfe, P.E., M.ASCE
Ashly Cabas Mijares, Ph.D., A.M.ASCE
Marta Miletić, Ph.D.
Matteo Montesi, P.E., M.ASCE
Ramin Motamed, Ph.D., P.E., M.ASCE
Ara G. Mouradian, P.E., M.ASCE
Boo Hyun Nam, Ph.D., A.M.ASCE
Peter A. Narsavage, P.E., M.ASCE
Miguel A. Pando, Ph.D., P.E., M.ASCE
Menzer Pehlivan, Ph.D., P.E., M.ASCE
William K. Petersen, P.E., M.ASCE
Rafael A. Prieto Piedrahita, Ph.D., P.E., Ing., M.ASCE
Krishna R. Reddy, Ph.D., P.E., D.GE, ENV SP, F.ASCE
David A. Saftner, Ph.D., A.M.ASCE
Hosam Salman, P.E., F.ASCE
Kristin Sample-Lord, Ph.D., P.E., M.ASCE
Inthuorn Sasanakul, Ph.D., P.E., M.ASCE
Kallol Sett, Ph.D., A.M.ASCE
Michael R. Simac, P.E., M.ASCE
Timothy D. Stark, Ph.D., P.E., D.GE, F.ASCE
Sam Sternberg, III, P.E., M.ASCE
Muhannad T. Suleiman, Ph.D., A.M.ASCE

**© ASCE**

Burak F. Tanyu, Ph.D., C.Eng, M.ASCE
Junliang Tao, Ph.D., A.M.ASCE
Stacey E. Tucker-Kulesza, Ph.D., P.E., M.ASCE
Leon A. Van Paassen, Ph.D., Aff.M.ASCE
Daniel R. Vanden Berge, Ph.D., P.E., M.ASCE
Sotirios Vardakos, Ph.D., A.M.ASCE
Andrea L. Welker, Ph.D., P.E., M.ASCE
Clinton M. Wood, Ph.D., A.M.ASCE
Martin Woodard, Ph.D., P.G., P.E.
Zia Zafir, Ph.D., G.E., P.E., M.ASCE
Xiong Zhang, Ph.D., P.E., A.M.ASCE

## 2019 Geo-Congress Paper Reviewers

Aiyoub Abbaspour
Sherif Abdelaziz
Sherif Abdelsalam
Tarek Abichou
Grace Abou-Jaoude Estephan
Murad Abu-Farsakh
Tiffany Adams
Alireza Afshani
Victor Aguilar
Rafael Aguilar Velez
Asif Ahmed
Junaid Ahmed
Mohammad Ahsanuzzaman
Beena Ajmera
Idil Akin
Arif Ali Baig Moghal
Ihab Allam
Robert Alperstein
Ali Al-Saadi
Mohammed Alsalihi
Daniel Alzamora
Brian Anderson
Donald Anderson
Mohamed Arab
Luis Arboleda-Monsalve
Allam Ardah
Moi Arzamendi
Mojdeh Asadollahi Pajouh
Jeremy Ashlock
Muhammad Asim Ayaz
Kamelia Atefi Monfared
Kleio Avrithi
Paul Axtell
Mohammad Azadi
Eric Backlund
William Baker
Aritra Banerjee
Sujan Baral
Christopher Bareither
Tugce Baser
Christopher Baxter
Melissa Beauregard
Ryan Beemer
Aaron Berkes
K.P. Bhargav Kumar
Amit Bhasin
Shobha Bhatia
Aditya Bhatt
Riya Bhowmik
Britta Bienen
Gregory Biesiadecki
Kari Bigham
Jobair Bin Alam
Tanner Blackburn
Antonio Bobet
Andrew Boeckmann
Gretchen Bohnhoff
Ademola Bolarinwa
Ross Boulanger
Stan Boyle
Aaron Bradshaw
Scott Brandenberg
Thomas Brandon
Michael Brannon
Mark Breitnauer
Jeremy Brown
Donald Bruce
Sebastian Bryson
Aaron Budge

© ASCE

Kristi Bumpas
Susan Burns
Brandon Buschmeier
Ashly Cabas Mijares
John Caccese
Daniel Cacciola
Carlos Calderon Macias
William Camp
David Campo
Junnan Cao
Camilo Cardona
Ethan Cargill
Kevin Cargill
Timothy Carlin
Clinton Carlson
Norman Carlson
Nina Carney
Bernardo Castellanos
Raymond Castelli
Elvis Castillo-Camarena
Ignazio Cavarretta
Nilo Cesar Consoli
Sayantan Chakrabaty
Kaye Chancellor
Carlos Chang
Erik Charrier
Kaustav Chatterjee
Santiram Chatterjee
Can Chen
Liang Chern Chow
Jyoti Chetri
Bhaskar Chittoori
Byoung Cho
Ishika Chowdhury
Jose Clemente
Charles Coccia
Joseph Coe
Richard Coffman
David Connolly
Brady Cox
Robert Crawford
Kaley Crawford-Flett
Raphael Crowley
W Cui
Todd Culp
Sheng Dai
John Damm
John Daniels
Vishal Dantal
Jasaswee Das
Shideh Dashti
Jyotishka Datta
John Davie
Dinu Davis Arakkal
Haitham Dawood
Tayler Day
Anirban De
Hubert Deaton
Carl Debono
James Delimitros
Joel Dellaria
Melih Demirkan
Norman Dennis
Daniel Dias
Guillermo Diaz-Fanas
Vansittee Dilli Rao
Jerry DiMaggio
Dan Ding
Vishnu Diyaljee
Yi Dong
Aliasghar Dormohammadi
Joseph Dunbar
Adrian Eberemu
John Edens
Herbert Einstein
May El Khattab
Omar El Khoury
Usama El Shamy
Fathey Elsaid
David Elwood
Rehab Elzeiny
Alan Esser
Jongwan Eun
Jeffrey Evans
Ahmed Faheem
Aly Fahmy
Hamid Fallah
Fadi Faraj
Hadi Fatehi
Aria Fathi
Alomir Favero Neto
Americo Fernandez
Marianna Ferrara
Matteo Ferrucci
Richard Finnoi
Ali Firat Cabalar
Maziar Foroutan
Kevin Foye
Raymond Frantz
Dante Fratta
Brian Freilich
Michael Fritzges
Mohammed Gabr
Mahi Galagoda
Khaled Galal

© ASCE

Patricia Gallagher
Aaron Gallant
Fernando Garcia
Luis Garcia
Victor Garcia
Mauricio Garcia Theran
Sarah Gassman
Philip Gauffreau
Donald Gerken
Hande Gerkus
Ismail Ghaaowd
Omid Ghasemi-Fare
Majid Ghayoomi
Ehsan Ghazanfari
Ehsan Ghazanfari
Shahin Ghazizadeh
Amin Gheibi
Emad Gheibi
Malay Ghose Hajra
Priyanka Ghosh
Sayantani Ghosh
James Gingery
Maria Giovanna Durante
Elizabeth Godfrey
Seda Gokyer
Helena Gomes
Jesus Gomez
Michael Gomez
Guobin Gong
Hongren Gong
Jared Green
Garry Gregory
Athina Grizi
Athina Grizi
Fan Gu
Lei Gu
Nenad Gucunski
Ranjiv Gupta
Sukh Gurung
Marte Gutierrez
Ivan Guzman
Hamid Haddadi
Tarik Hadj-Hamou
Caitlyn Hall
Kaitlin Hall
Kevin Hall
Nasser Hamdan
Sherif Hanna
Jonathan Harris
Youssef Hashash
Mehrdad Hassani
Toshiro Hata
Carol Hawk
Nathan Hayman
Reza Hedayat
Alexander Herzog
Amanda Hess
Carlton Ho
Tasha Hodges
Terry Holman
Edward Hoppe
Shabbir Hossain
Arash Hosseini
Isaac Howard
Liangbo Hu
Jie Huang
Peter Hubbard
Jonathan Hubler
Nick Hudyma
James Hussin
Nejan Huvaj Sarihan
Boo Hyun Nam
Gabriel Iltis
Marco Isola
Dan Jackson
Rowshon Jadid
Navid Jafari
Daniel Jankly
Carlos Jaramillo
Carlos Jaramillo
Priyantha Jayawickrama
Erik Jensen
Pravin Jha
Pravin Jha
Chunyang Ji
Chu Jian
Sarah Johnson
Allen Jones
Tucker Jones
Guillermo Jose Zavala Rosell
Maureen K Corcoran
Onur Kacar
Mehdi Kadivar
James Kaklamanos
Viktor Kaliakin
Arash Kamali-Asl
Edward Kavazanjian
Andrew Keffer
Behnoud Kermani
Majid Khabbazian
Taha Khalaff
Yazen Khasawneh
Hamed Khodadadi
Sara Khoshnevisan
Ali Khosravi

© ASCE

Mohammad Khosravi
Arash Khosravifar
Naji Khoury
Dong-soo Kim
Eunhye Kim
Marcus Kim
Sihyun Kim
Taehong Kim
Eric Klein
Weston Koehn
George Koerner
Sreevalsa Kolathayar
Prabir Kolay
Joshua Kolz
Van Komurka
Alireza Kordjazi
Joseph Krupansky
Levi Kryder
Jeffrey Kuhn
Stacey Kulesza
Ashutosh Kumar
Girish Kumar
Pratap Kumar
Rakesh Kumar
Sanjeev Kumar
Dilip Kumar Baidya
Anil Kumar Choudhary
Sujit Kumar Dash
Anil Kumar Sharma
Sanjay Kumar Shukla
Jan Kupec
Walter Kutschke
Welson Kwan
Tae-Hyuk Kwon
Joseph Labuz
Debra Laefer
Rakam Lama Tamang
Joan Larrahondo
Sam Lasley
Michael Law
Mauakanta Ldon
Jongwon Lee
Michelle Lee Barry
Gang Lei
Ben Leschinsky
Ben Leschinsky
Michael Lewis
Junhong Li
Kun Li
Lin Li
Marina Li
Xin Liao
Cheng Lin
Tim Lin
Bret Lingwall
Zhen Liu
Erik Loehr
John Lommler
Roberto Lopez
Theresa Loux
Barbara Luke
Ronaldo Luna
Matthew Lunemann
David Lutz
Scott Mackiewicz
Mary MacLaughlin
Brian Maggi
Nariman Mahabadi Mahabad
Abinash Mahanta
Farzaneh MahmoodPoor
Enad Mahmoud
Siavash Mahvelati
Roman Makhenko
Islam Mamdouh Ezz
Shahed Manzur
Benjy Marks
Landon Marston
Grant Martin
Alejandro Martinez
Meysam Mashayekhi
Ben Mason
Frederic Masse
Brett Maurer
Carlos Mauricio Rodriguez
Nathan Mayercsik
Mehran Mazari
John McCartney
Ken McCleskey
Monica McCullough
Ross McGillivray
Michael McGuire
James McKelvey
Christopher McKenney
Steven McMullen
Patrick McNamara
Karim Md Zahidul
Zenon Medina-Cetina
Keithe Merl
Scott Merry
Brian Metcalfe
Paul Michaels
Marta Miletic
Marc Miller
Morteza Mirsekari
Debakanta Mishra

© ASCE

Rozbeh Moghadaam
Merhab Moid
Hossain MollaAbbasi
Matteo Montesi
Jack Montgomery
Brina Montoya
Michael Mooney
Alesandra Morales
Ali Morovatdar
Joseph Morris
Kimia Mortezaei
Sarah Morton
Ramin Motamed
Masoud Mousavi
Sukjoon Na
Maheboobsab Nadaf
Ashkan Nafisi
Dali Naidu Arnepalli
Peter Narsavage
Kalehiwot Nega Manahiloh
Albert Neumann
Peter Neumann
Madan Neupane
Roberto Nevarez Garibaldi
David Nevius
Kam Ng
Thang Nguyen
Peter Nicholson
Jennifer Nicks
Alexandros Nikellis
Sissy Nikolaou
Sanjay Nimbalkar
Zhangwei Ning
Mary Nodine
Sean O'Connell
Lalita Oka
Roberto Olivera
Kimball Olsen
Larry Olson
Scott Olson
Thomas Oommen
Omar Osama El-Shafee
K.J. Osinubi
Abdolreza Osouli
William Ovalle
Anindya Pain
Angel Palomino
Miguel Pando
Sarath Panthangi
Balaji Paramasivam
Siddarth Parida
Choon Park
Youngjin Park
Trent Parkhill
Jonathan Pasco
Ujwalkumar Patil
Aravind Pedaria
Menzer Pehlivan
William Petersen
Vinh Pham
Adrienne Phillips
James Phipps
Alan Poeppel
Tyler Poggiogalle
Carmine Polito
William Pollock
Mihail Popescu
Alex Potter-Weight
Daniel Pradel
Amit Prashant
James Press
Russ Preuss
Adam Price
Rafael Prieto
Jean Provost
Aaron Pullen
Tong Qiu
Ata Radfar
Amin Rafiei
Amr Ragy
Mehrzad Rahimi
Mostaqur Rahman
Raksha Rai
B Ram Rathan Lal
Sarah Ramp
Scott Raschke
Mohammad Rashidi
Ellen Rathje
Nadarajah Ravichandran
K.V.N.S. Raviteja
Deepak Rayamajhi
Krishna Reddy
Alex Reeb
Alex Reeb
Bridgit Reeve
Jose Ricardo Pontes Resende
Stephen Richards
Jesse Richins
Matthew Riegel
Stefano Rignanese
Helen Robinson
Nicholas Rocco
Adrian Rodriguez-Marek
Mark Rohrbach
Kyle Rollins

© ASCE

Brent Rosenblad
Jason Ross
Mary Roth
Michael Rucker
Cassandra Rutherford
M Sabry
Mohammad Sadik Khan
Arezoo Sadrinezhad
David Saftner
Rajni Saggu
Mohammad Saghafi
Sajjad Salam
Reza Salehi Ashtiani
Hosam Salman
Kristin Sample-Lord
Naresh Samtani
Tony Sangiuliano
Ritika Sangroya Kundu
Nicoletta Sanvitale
Surya Sarat Chandra Congress
Raghav Sarathy Ramanathan
Inthuorn Sasanakul
Joseph Scalia
Lilma Schimmel
Kurt Schimpke
Montgomery Schultz
Ian Scotland
Kevin Scott
Peter Scott
Jeff Segar
Asitha Senanayake
Hoyoung Seo
James Serpico
Kallol Sett
Emel Seyhan
Alejo Sfriso
Charles Shackelford
Shahriar Shahrokhabadi
Keshab Sharma
Megha Sharma
Shweta Shrestha
Xiang Shu
Phil Shull
Shafiq Siddiqui
Timonthy Siegel
Francisco Silva-Tulla
Michael Simac
Lyle Simonton
Sugandha Singh
Matthew Sleep
Joel Sloan
Alex Smith
Miriam Smith
David Snyder
Konstantin Sobolev
Antonio Soldo
Behzad Soltanbeigi
Yasser Soltanpour
R Sridhar
Ioannis Stefanou
Isaac Stephens
Sam Sternberg III
Eric Steward
Shelley Stoffels
Armin Stuedlein
Muhannad Suleiman
Richard Sullivan
Lixun Sun
Oscar Suncar Garcia
David Sutfin
Nico Sutmoller
Robert Swan
Bryan Sweeney
Matthew Sylvain
David Taborda
Amir-Ata Taghavi
Abbasali Taghavighalesari
Gilbert Tallard
Claudio Tamagnini
Prajwol Tamrakar
Yong Tan
Hui Tao
Junliang Tao
Thomas Taylor
Thomas Terry
Audai Theinat
Mark Thompson
Cesar Tirado
Binod Tiwari
Dominique Tobler
Ingrid Tomac
Fulvio Tonon
Khiem Tran
Tri Tran
Aurelian Trandafir
Anne Turner
Benjamin Turner
Erol Tutumluer
Edward Ulrich
Farshid Vahedifard
Rouzbeh Vakili
Rick Valentine
Luis Vallejo
Leon Van Paassen

© ASCE

Sai Vanapalli
Daniel VandenBerge
Wouter Vanderstar
Lee Vanzler
Sotirios Vardakos
Mehdi Veiskarami
Pavana Vennapusa
Osvaldo Vitali
Pavlo Voitenko
Antonios Vytiniotis
Assil Wajdi Abu Diab
Tanya Walkenbach
P Wallbridge
Helsin Wang
Lei Wang
Shin-Tower Wang
Kimberly Warren
Alexandra Wayllace
Jeffrey Weidner
Andrea Welker
Cassandra Wetzel
Kord Wissmann
Daniel Woeste
Louis Wong
Clinton Wood
Dylan Wood
Martin Woodard
Chris Woods
Robert Worley II
Donald Wotring
Zhenzhong Wu
Ming Xiao
Yilong Xiao
Yonggui Xie
Jun Yao
Walter Yerk
Nazli Yesiller
Ronald Yeung
Samuel Yniesta
Xiaomin You
Xinbao Yu
Xiong Yu
Michael Yust
Zia Zafir
Mohammad Zahidul Islam Bhuiyan
Atefeh Zamani
Luis Zambrano-Cruzatty
Siavash Zamiran
Kaveh Zehtab
Dimitrios Zekkos
Bo Zhang
Lianyang Zhang
Ming Zhang
Wen-jie Zhang
Xiong Zhang
Yan Zhang
Aigen Zhao
Jian Zheng
Junxing Zheng
Yewei Zheng
Shengyang Zhou
Ming Zhu
Thomas Zimmie
Katerina Ziotopoulou
Daren Zywicki

© ASCE

# Contents

*Computational Geotechnics*

**Mesh Size Sensitivity and Effect of Perturbation Intensity on Coupled Undrained Instability Analysis in Sands ..... 1**
Debayan Bhattacharya and Amit Prashant

**Simulation of the Cutting Process in Softening and Hardening Soils ..... 11**
Zhefei Jin and James P. Hambleton

**Numerical Modeling of Structural Backfills for Transportation Infrastructure ..... 20**
Meysam Mashayekhi, Victor N. Kaliakin, Christopher L. Meehan, Michael T. Adams, and Jennifer E. Nicks

**Influence of Particle Rolling and Rotation on the Shearing Response of Clean Sand ..... 30**
Nick Barnett, Md. Mizanur Rahman, Md. Rajibul Karim, and Hoang Bao Khoi Nguyen

**The Phase Transformation under Undrained and Drained Triaxial Conditions by the Discrete Element Method ..... 40**
H. B. K. Nguyen, M. M. Rahman, and M. R. Karim

**Models for Estimation of Lightweight Deflectometer Moduli for Unbound Materials ..... 48**
Aria Fathi, Cesar Tirado, Mehran Mazari, and Soheil Nazarian

**Performance of Bounding Surface Constitutive Models in Predicting Cyclic Behavior of Low-Plasticity Fine-Grained Soils ..... 57**
Mohammad M. Eslami, Mohammad Zarrabi, and Samuel Yniesta

**Numerical Analysis of Radial Consolidation with Discharge Capacity Reduction Using Finite Strain Theory ..... 67**
Ba-Phu Nguyen and Yun-Tae Kim

**Numerical Analysis on Feasibility of Thermally Induced Pore Fluid Flow in Saturated Soils ..... 73**
Mohammadreza Mir Tamizdoust and Omid Ghasemi-Fare

**Modeling the Impact Force from a Dry Granular Flow Using Smoothed Particle Hydrodynamics Method ..... 83**
Bahman Sheikh and Tong Qiu

**Nonlinear Dynamic Analysis of Track Embankments for High-Speed Trains ..... 95**
Negin Yousefpour and Eden Almog

© ASCE

**Numerical Insight into the Geotechnical Mechanisms Triggering Failure at the Winter Park Sinkhole in Florida** ..... **106**
Moataz Soliman, Luis G. Arboleda-Monsalve, and Boo Hyun Nam

**Numerical Modeling of a Free Fall Penetrometer Deployment Using the Material Point Method** ..... **116**
Luis Zambrano-Cruzatty, Alba Yerro, and Nina Stark

**Thermo-Mechanical Behavior of Saturated Clays Using Discrete Element Modelling** ..... **125**
Karam A. Jaradat and Sherif L. Abdelaziz

**Bearing Capacity of a Strip Footing Situated on Reinforced Cohesionless Soil Slope Using Non-Associated Flow Rule** ..... **135**
K. Halder and D. Chakraborty

**Flat Plate Dilatometer and Finite Element Analysis in Evaluation of Settlement Induced Effects on Utilities** ..... **145**
Dylan Brancato, E. Gregory McNulty, Bill Little, and Timothy Williams

**Effect of Particle Size on High-Strain Rate Response of Sand** ..... **155**
Sudheer Prabhu and Tong Qiu

**The Effects of Stress Redistribution on the Propagation of Stress Waves beneath the Bottom of Drilled Shaft Excavations** ..... **165**
Alireza Kordjazi and Joseph T. Coe

**Coupled Analysis of Wave, Structure, and Sloping Seabed Interaction: Response and Instability of Seabed** ..... **175**
Amin Rafiei, M. S. Rahman, and M. A. Gabr

**Probabilistic Analysis of a MSE Wall Considering Spatial Variability of Soil Properties** ..... **184**
Sina Javankhoshdel, Brigid Cami, Thamer Yacoub, and Richard J. Bathurst

**Three-Dimensional Finite Element Analysis of Reinforced Concrete Box Culverts Using Infinite Elements** ..... **193**
Christy L. Bugher, Kalehiwot Nega Manahiloh, Victor N. Kaliakin, and Harry W. Shenton

***Pavements***

**Development of a Strength Prediction Model for Recycled Base Materials with Soil Intrusion** ..... **204**
Prabesh Bhandari, Sita Timsina, Asif Ahmed, Md. Sahadat Hossain, and Boon Thian

© ASCE

**Plate Load Testing on Layered Pavement Foundation System to Characterize Mechanistic Parameters ..... 214**
David J. White, Pavana Vennapusa, Jeffery R. Roesler, and William Vavrik

**Enhanced Lateral Drainage Geotextile to Mitigate the Effects of Moisture Migration from a High Water Table ..... 227**
Anthony El Hachem and Jorge G. Zornberg

**Subgrade Soil Stabilization Using Low-Quality Recycled Concrete Aggregate ..... 235**
Masoumeh Tavakol, Mustaque Hossain, and Stacey E. Tucker-Kulesza

**Long-Term Field Performance of Geosynthetics in Pavement Subgrades in Virginia ..... 245**
M. Shabbir Hossain, Edward J. Hoppe, and Chaz B. Weaver

**Cyclic Triaxial Tests on Crushed Limestone for Base Layers ..... 259**
Pradip Adhikari and Abdolreza Osouli

**Laboratory Testing of an Externally-Heated Bridge Deck Subjected to Wind ..... 268**
Mark Hurley, Gang Lei, and Xinbao Yu

**Using Soil-Moisture Active Passive Satellite Data to Evaluate the Performance of Transportation Infrastructure Foundations—A Feasibility Study ..... 278**
Simon Packman, Sonya Lopez, Aria Fathi, and Mehran Mazari

**Mechanical Concrete for Enhancing the Properties of Pavement Base/Subbase ..... 287**
P. V. Vijay and Justin S. Smith

**Cyclic Plate Load Testing for Assessment of Asphalt Pavements Supported on Geogrid Stabilized Granular Foundation ..... 296**
David J. White, Pavana Vennapusa, John Siekmeier, and Heath Gieselman

**Parametric Study of Modified Subgrade Reaction Model Using Artificial Neural Network Approach ..... 308**
Sajib Saha, Fan Gu, Xue Luo, and Robert L. Lytton

**Sustainable Design of Rigid Pavements Using a Hybrid GP and OLS Method ..... 317**
Abbasali TaghaviGhalesari and Carlos M. Chang-Albitres

**Development of the Virtual Load Method by Applying the Inverse Theory for the Analysis of Geosynthetic-Reinforced Pavement on Expansive Soils ..... 326**
Debojit Sarker, Jay X. Wang, and Md. Adnan Khan

© ASCE

**Use of Pervious Concrete in Developing Countries for Stormwater Management** ..... **340**
Naji Khoury, Louis Junior Saad, and Charles Saad

**Performance Evaluation of Pavement Subgrade by In Situ Moisture and Matric Suction Measurements** ..... **347**
Pratibha Pandey, Asif Ahmed, Anuja Sapkota, Md. Sahadat Hossain, and Boon Thian

**Assessment of Geotextile Effectiveness in Decreasing Subgrade Pumping and Increasing Service Life in Rigid Pavements Using Scaled Model Mobile Load Simulator** ..... **357**
Behnoud Kermani, Shelley M. Stoffels, and Ming Xiao

**Case Study of Military Airfields Emphasizing Asset Management, Rehabilitation, and Implementation of New Technologies** ..... **368**
Thomas M. Synovec, Isaac L. Howard, and Lucy P. Priddy

**Effect of Fine Clay Particles on the Strength Characterization of Cement Treated Flex-Base Materials** ..... **382**
Sita Timsina, Prabesh Bhandari, Md. Nur Basit Zaman, Asif Ahmed, Md. Sahadat Hossain, and Boon Thian

**Mix Design of Roller Compacted Concrete Pavement Using Steel Slag By-Products** ..... **391**
Charbel Khoury, Kofi B. Acheampong, and Kwabena Ofori-Awuah

**Assessment of Tactile Pressure Sensor for Measuring Interface Pressure in Mechanically-Stabilized Layers** ..... **402**
Madan Neupane, Jie Han, Robert L. Parsons, and Mike Horton

**Soil Freezing and Its Effects on Pavement Engineering by Random Finite Element Simulation** ..... **411**
Shaoyang Dong and Xiong (Bill) Yu

**Mechanistic Assessment of Layered Pavement Foundation System Using Validated Intelligent Compaction Measurements** ..... **421**
David J. White, Pavana Vennapusa, Erol Tutumluer, and Maziar Moaveni

**Case History of a Geosynthetic-Stabilized Base Roadway Founded over Expansive Clay Subgrade** ..... **430**
L. Zheng, G. H. Roodi, and J. G. Zornberg

**Impact of Stabilization of Expansive Clay with Corex Slag and Lime** ..... **444**
Radha J. Gonawala, Rakesh Kumar, and Krupesh A. Chauhan

© ASCE

*Rock Mechanics*

**Stability Assessment of Large Caverns in Horizontally Bedded Strata Considering Time-Dependent Response....454**
Mohammad Moridzadeh, Mohammad Djavid, and Barry Doyle

**Rock Slope Remediation at the Penobscot Narrows Bridge....464**
Bryan C. Steinert, Laura Krusinski, Amber B. Granger, and Wayne A. Chadbourne

**A Non-Stationary Power Law Model to Predict the Secondary Creep Rate of Rocks....476**
Ruofan Wang and Li Li

**Analysis and Comparison of Measured Static and Dynamic Moduli of a Dolostone Specimen....484**
K. C. Bijay, Maziar Foroutan, and Ehsan Ghazanfari

**Evaluation of the Material Durability and Classification of Rocks Used in the Anzali Port Breakwater....494**
V. Tohidi Karandagh, M. R. Nikudel, G. R. Lashkaripour, and B. Muhunthan

**Numerical Study on Thermally-Induced Displacement Ratcheting of a Thin Rock Slab....506**
Sihyun Kim, Ethan Druszkowski, Jingtao Zhang, and Seunghee Kim

**Study on the Geochemical Characteristics and Weathering Behavior of Black Shale....514**
Jian Li, Xin Liao, Kangji Wang, Xiyong Wu, Jiannan Chen, and Yingwei Xi

**Thermal Effects on Reservoir-Sealing Rock Interactions during Injection and Production Operations....522**
Xinle Zhai and Kamelia Atefi-Monfared

*Soil Properties and Modeling*

**Drying Changes Consistency Limits....532**
Emre Uyeturk and Nejan Huvaj

**Optimal Deformation Modes for Estimating Soil Properties....541**
Anastasia Nally, Zhenhao Shi, and James P. Hambleton

**Influence of Temperature Variation on Complex-Impedance Measuring Instrument Test Results....551**
Jason S. Hertz and Christopher L. Meehan

**Progressive Change in Shear Strength of Yazoo Clay....560**
M. S. Khan, J. Ivoke, and M. Nobahar

© ASCE

**Electrical Resistivity Measurements in Advanced Triaxial Tests ..... 570**
Wing Shun Kwan, Mark Tufenkjian, James Tuazon, Niccolas Peralta, Kenny Khov, and Freddy Garcia

**Effect of Wet-Dry Cycle on the Void Ratio of Expansive Yazoo Clay ..... 580**
M. S. Khan, J. Ivoke, M. Nobahar, and G. Kibria

**Frequency Effects on Low-Strain Shear Modulus and Damping for Natural Clays and Silts ..... 590**
Pitak Ruttithivaphanich and Inthuorn Sasanakul

**Permanent Deformation Characteristics of Coarse Grained Subgrade Soils Using Repeated Load Triaxial Tests ..... 599**
Md. Mostaqur Rahman and Sarah L. Gassman

**Fatigue Crack Propagation in Stiff Clays Forming Part of Earth Dams and Natural Slopes ..... 610**
Luis F. Vallejo and Mahiru Shettima

**Visualizing the Role of Particle Shape on 2D Inter-Particle Fluid Flow Using a Transparent Soil Surrogate ..... 618**
Linzhu Li, Mehdi Omidvar, Stephan Bless, and Magued Iskander

**Scale Effects in the Indirect Tensile and Unconfined Compressive Strength Tests of Cement-Stabilized Base Materials ..... 628**
Mohammad Rashidi and Reza S. Ashtiani

**Impact of Biology on Particle Crushing in Offshore Calcareous Sediments ..... 640**
Ryan D. Beemer, Aleksey Sadekov, Ulysse Lebrec, Jeremy Shaw, Alexandre Bandini-Maeder, and Mark J. Cassidy

**Bayesian Probabilistic Approach to Assess the Compression and Recompression Indices of Over-Consolidated Expansive Clays ..... 651**
Yasser Soltanpour and Hosam Salman

**Estimating Optimal Additive Content for Soil Stabilization Using Machine Learning Methods ..... 662**
Amit Gajurel, Partha Sarathi Mukherjee, and Bhaskar Chittoori

**Oedometric Behavior of a Diatom-Kaolin Mixture ..... 673**
Hend H. Al Shatnawi and Paola Bandini

**Development of a One-Dimensional Heating Soil Test Cell ..... 682**
Gang Lei, Nice Kaneza, Xinbao Yu, Teng Li, and Omid Habibzadeh-Bigdarvish

© ASCE

**Accounting for Strain Rate Dependent Behavior during Consolidation of Saturated Clay ..... 691**
Ross W. Boulanger and Scott J. Brandenberg

**Prediction of Unconfined Deformation Behavior of Soils Using Electrical Properties ..... 701**
Majid Mahmoodabadi and L. Sebastian Bryson

*Unsaturated Soils*

**A Procedure for Incorporating Climatic and Water Table Data in the Geotechnical Design of Driven Pile Subjected to Axial Load ..... 711**
Vahidreza Mahmoudabadi and Nadarajah Ravichandran

**Evaluation of Post-Construction Changes in Soil Hydraulic Properties through Field Instrumentation and In Situ Testing ..... 722**
Md. Jobair Bin Alam and Md. Sahadat Hossain

**Effect of Geotechnical Parameters on the Percolation Performance of an Established Rain Garden in Pennsylvania ..... 733**
Wessam Mohammed, Andrea L. Welker, and James Press

**Evaluation of Unsaturated Soil Seepage and Protection of Basement Slab during Flooding ..... 743**
Ajay Shastri, Ram Kasturi, and Ram Tirumala

**Evaluation of Bimodal Water Retention Characteristics for Hydrating Chromium Ore Processing Residue (COPR) ..... 754**
Mostafa Afzalian, Jongwan Eun, and James M. Tinjum

**Numerical Investigation of a Saturated and Unsaturated Soil-Atmosphere Model ..... 765**
Chuang Lin and Xiong Zhang

**Effect of Lime Stabilization on the Unsaturated Hydraulic Conductivity of Clayey Soil in Texas ..... 773**
Puneet Bhaskar, Burak Boluk, Aritra Banerjee, Ali Shafikhani, and Anand Puppala

**Measuring Thermal Conductivity of Unsaturated Sand under Different Temperatures and Stress Levels Using a Suction-Controlled Thermo-Mechanical Method ..... 784**
Jun Yao, Tengfei Wang, and William J. Likos

**Measurement of Thermal Conductivity Dryout and SWCC Curves for Sands Using a Modified Hanging Column Device ..... 794**
Xuelin Wang, Xinbao Yu, Nice Kaneza, and Shi He

© ASCE

**Characterizing the Unsaturated Strength Behavior of a Native Transition Soil Used as Backfill in the Construction of U.S. 301, Section 3 ..... 804**
Mehdi Kadivar, Kalehiwot Nega Manahiloh, and Victor N. Kaliakin

**Stability of Unsaturated Sand Beds in the Intertidal Zone during Tsunami Loading ..... 814**
Babak Mahmoodi, Aaron P. Gallant, and H. Benjamin Mason

**Large-Scale Rainfall Simulation and Cyclic Plate Loading Test of Wicking Geotextile-Stabilized Base ..... 824**
Jun Guo, Jie Han, and Xiong Zhang

**A Bounding Surface Based Constitutive Model for Unsaturated Granular Soils ..... 833**
Mehdi Kadivar, Kalehiwot Nega Manahiloh, and Victor N. Kaliakin

**Stability Analysis of an Unsaturated Silty Slope under Nonisothermal Conditions ..... 844**
Sannith Kumar Thota, Toan Duc Cao, Farshid Vahedifard, and Ehsan Ghazanfari

**Shear-Induced Matric Suction in Unsaturated Clayey Sand during Constant Water Content Triaxial Tests ..... 853**
Muwafaq Awad and Inthuorn Sasanakul

© ASCE