

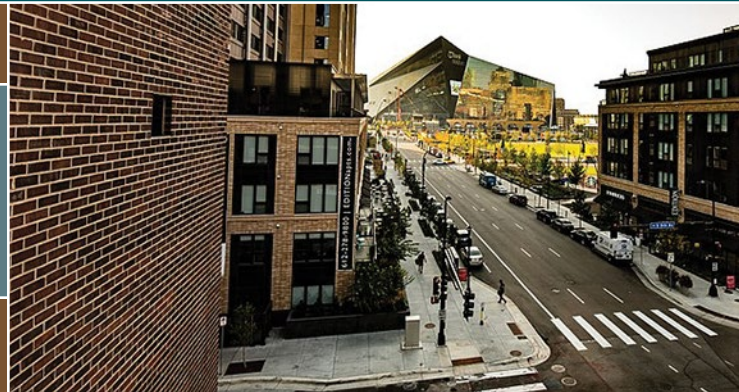


Geo-Congress 2020

GSP 319

Geo-Systems, Sustainability,
Geoenvironmental Engineering, and
Unsaturated Soil Mechanics

Selected Papers from the Geo-Congress 2020
Minneapolis, Minnesota
February 25–28, 2020



ASCE

Edited by

James P. Hambleton, Ph.D.;
Roman Makhnenko, Ph.D.: and



**GEO-
INSTITUTE**

This is a preview. [Click here to purchase the full publication.](#)

GEOTECHNICAL SPECIAL PUBLICATION NO. 319

GEO-CONGRESS 2020

*GEO-SYSTEMS, SUSTAINABILITY, GEOENVIRONMENTAL
ENGINEERING, AND UNSATURATED SOIL MECHANICS*

SELECTED PAPERS FROM SESSIONS OF
GEO-CONGRESS 2020

February 25–28, 2020
Minneapolis, Minnesota

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

EDITED BY
James P. Hambleton, Ph.D.
Roman Makhnenko, Ph.D.
Aaron S. Budge, Ph.D., P.E.



Published by the American Society of Civil Engineers

This is a preview. [Click here to purchase the full publication.](#)

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/10.1061/9780784482827>

Copyright © 2020 by the American Society of Civil Engineers.
All Rights Reserved.
ISBN 978-0-7844-8282-7 (PDF)
Manufactured in the United States of America.

Preface

This is the fifth of seven volumes containing the full collection of papers presented at Geo-Congress 2020: Vision, Insight, Outlook on February 25-28, 2020 in downtown Minneapolis, MN. These seven volumes include well over 400 contributions that span the 20 topic areas of the ASCE Geo-Institute's standing technical committees as well as 11 special topics unique to Geo-Congress 2020:

- **Geotechnics of Coasts, Oceans, Ports, and Rivers:** Subaqueous sediment characterization; slope stability problems; slope and coastal erosion problems; geotechnics of numerical and field studies of marine foundations.
- **“Common Ground” Geotechnical Issues Shared by the US and Canada:** Border projects and topics of international interest; Example: Projects along the great lakes, peat, permafrost, and railways.
- **50th Anniversary of Minnesota Geotechnical Society (MGS):** University of Minnesota 68th Annual Geotechnical Conference; Kersten Lecture; Invited international speakers; Local and regional projects and case histories; Example: Geotechnics of MN sports stadiums.
- **The Geotechnics of Alternative Project Delivery:** Impact of project procurement (traditional, CMGC, DB, P3) on geotechnics; Performance-based work.
- **Geo-Education:** Trends in geotechnical engineering education; Incorporating research into education; Use of case histories in education.
- **Construction, Inspection, and Monitoring:** Innovative monitoring techniques; UAS inspection; LiDAR; Photogrammetry; Thermal imaging in geoconstruction.
- **Advances in Geo-Computing:** Cloud computing; Numerical methods; Visualization techniques; Geotechnical engineering and the fourth dimension.
- **Geo-Systems:** Integration of geotechnical engineering with other science and engineering disciplines; Biogeotechnical engineering; Geo-structural engineering; Hydraulics; Scour-soil transport; Beyond the thermal pile: geothermal application.
- **Geo-Forensics:** Hindsight is 20/20: failure case histories; Multi-disciplinary teams for geotechnical failure investigations; Have we really learned from past failures? Does history always need to repeat itself?
- **Geo-Ethics:** Socially responsible geotechnical practice; Reporting of geotechnical data; Are we as confident as we appear on paper? Geotechnical engineers, risk, responsibility, and the legal system.
- **States of Stress:** Examining challenges of our practice; Moving forward in a dynamic and rapidly changing world; Responding to the priorities and needs of civil infrastructure within the constraints and demands related to time, talent, budget, coordination, and communication.

Of the topics above, the first three are an outcome of partnerships with the Coasts, Oceans, Ports, and Rivers Institute (COPRI) of ASCE, the Canadian Geotechnical Society, and MGS. Additionally, papers were solicited and submitted in collaboration with the Center for Bio-mediated and Bio-inspired Geotechnics directed by Dr. Edward Kavazanjian from Arizona State University. A number of papers were also received as part of special sessions proposed by conference participants.

The seven volumes in this series for Geo-Congress 2020 include five volumes arranged by topic area and two special volumes: one dedicated to the emerging field of biogeotechnical engineering and the other dedicated to papers collected and reviewed by MGS on the occasion of its 50th Anniversary. Each of the seven volumes are Geotechnical Special Publications (GSPs), containing papers that were reviewed in accordance with ASCE GSP standards. Each paper was subjected to technical review by two or more independent peer reviewers, and publication required concurrence by at least two peer reviewers.

The Editors gratefully acknowledge the immeasurable contributions of the countless individuals who made Geo-Congress 2020 and these published proceedings possible, especially the reviewers, sessions chairs, organizing committee members, and ASCE staff listed in the acknowledgements.

The Editors,

James P. Hambleton, Ph.D., M.ASCE, Northwestern University
Roman Makhnenko, Ph.D., A.M.ASCE, University of Illinois at Urbana-Champaign
Aaron S. Budge, Ph.D., P.E., M.ASCE, Minnesota State University, Mankato

Acknowledgments

The conference and its published proceedings would not have been possible without the diligent, coordinated effort of numerous people, especially the reviewers who provided detailed feedback on papers and the session chairs who made decisions and provided editorial assistance on selected topics. These individuals are recognized below. The editorial team is also profoundly grateful to Mr. Derrick Dasenbrock (Conference Chair), Dr. Roman Hryciw (Technical Program Co-Chair), Dr. Nick Hudyma (Technical Program Co-Chair), Dr. Nima Goudarzi, Mr. Brad Keelor, Ms. Erin Ryan, and the ASCE publications team for their crucial roles in the production of these proceedings.

Geo-Congress 2020 Conference Program Committee

Conference Chair

- Derrick D. Dasenbrock, P.E., D.GE, F.ASCE, Minnesota Department of Transportation

Technical Program Committee

- Roman D. Hryciw, Ph.D., M.ASCE, University of Michigan
- Nick W. Hudyma, Ph.D., P.E., M.ASCE, Boise State University
- Menzer Pehlivan, Ph.D., P.E., M.ASCE, Jacobs
- Lizan N. Gilbert, P.E., M.ASCE, Guy F. Atkinson Construction, LLC
- Jean Côté, Ph.D., Université Laval Québec (Representative, Canadian Geotechnical Society)
- Domenic D'Argenzio, P.E., M.ASCE, Mueser Rutledge Consulting Engineers (Representative, COPRI of ASCE)
- Brent A. Theroux, P.E., Barr Engineering Co. (Representative, Minnesota Geotechnical Society; Representative, University of Minnesota Annual Conference)

Proceedings Editors

- James P. Hambleton, Ph.D., M.ASCE, Northwestern University
- Roman Makhnenko, Ph.D., A.M.ASCE, University of Illinois at Urbana-Champaign
- Aaron S. Budge, Ph.D., P.E., M.ASCE, Minnesota State University, Mankato

Session Chairs

Idil Akin
 Glen Andersen
 Luis Arboleda
 Mojdeh Asadollahipajouh
 Kamelia Atefi Monfared
 Gregory Baecher
 Tugce Baser
 Dipanjan Basu
 Atilla Bayram
 Christine Beyzaei
 Scott Brandenburg
 Aaron Budge
 Ashly Cabas
 Bora Cetin
 Halil Ceylan
 Qiushi Chen
 Joseph Coe
 Douglas Cortes
 Jean Côté
 Domenic D'Argenzio
 Derrick Dasenbrock
 Chadi El Mohtar
 Usama El Shamy
 Fathey Elsaid
 Matt Evans
 Kevin Foye
 Omid Ghasemifare
 Majid Ghayoomi
 Ehsan Ghazanfari
 Lizan Gilbert

Bob Gilbert
 Milton Gomez
 Russell Green
 Ranjiv Gupta
 Jim Hambleton
 Jie Han
 Ahmadreza Hedayat
 Isaac Howard
 Laureano Hoyos
 Roman Hryciw
 Nick Hudyma
 Jie Hunag
 Navid Jafari
 Prabir Kolay
 Joseph Labuz
 Ben Leshchinsky
 Hai Lin
 Bret Lingwall
 Jerry Luo
 Kimberly Martin
 Rozbeh Moghaddam
 Brina Montoya
 James Myers
 Guney Olgun
 Thomas Oommen
 Abdolreza Osouli
 Adam Paisley
 Miguel Pando
 Ujwalkumar Patil
 Menzer Pehlivan

Tom Pennington
 Brent Rosenblad
 David Saftner
 Marcelo Sanchez
 James Schneider
 Charles Warren Schwartz
 George Segré
 Erin Sibley
 Lyle Simonton
 Tim Stark
 Muhannad Suleiman
 Binod Tiwari
 Farshid Vahedifard
 Leon van Paassen
 Sotirios Vardakos
 Eric Wang
 Lei Wang
 Mark Wayne
 Mike Wongkaew
 Clint Wood
 Xiong Yu
 Dimitrios Zekkos
 Xiong Zhang
 Limin Zhang
 Lianyang Zhang
 Yao Zhang
 Cheng Zhu
 Jorge Zornberg

Reviewers

John Abdalkhani
 Yasser Abdelhamid
 Murad Abufarsakh
 Robert Acker
 Orestis Adamidis
 Jeff Adams
 Sean Ahdi
 Asif Ahmed
 Bahar Ahou Ghalandari
 Beena Ajmera
 Idil Akin
 Hossein Alimohammadi
 Mehdi Alirezaei

Farshad Amini
 Mohsen Amirmojahedi
 Donald Anderson
 Nonika Antonaki
 Mona Anwar
 Luis Arboleda
 Lukas Arenson
 Pouyan Asem
 Jeremy Ashlock
 Kamelia Atefi Monfared
 Michel Aubertin
 Burcin Avar
 Kleio Avrithi

Aditya Ayithi
 Alireza Ayoubian
 Aritra Banerjee
 Christopher Bareither
 Tugce Baser
 Curt Basnett
 Chris Baxter
 Atilla Bayram
 Michael Beaty
 Saleh Behbahani
 Chris Behling
 Victoria Bennett
 Joseph Bentler

Ryan Berg	Douglas Cortes	Arman Ghaemi
Michelle Bernhardt	Mike Coryell	Abbasali Ghaesari
Christine Beyzaei	Jean Côté	Omid Ghasemifare
Raghu Bhargava	Jibril Coulibaly	Mohammad Ghavami
Tejo Bheemasetti	Vicky Curtis	Majid Ghayoomi
Dale C. Biggers	Sheng Dai	Ehsan Ghazanfari
Antonio Bobet	Domenic D'Argenzio	Amin Gheibi
Eric Boone	Derrick Dasenbrock	Malay Ghose Hajra
Amin Borghei	Biswajit Dasgupta	Lizan Gilbert
John Bowders	John Davie	Michael G. Gomez
Allen Bowers	Ricardo de Abreu	Milton Gomez
Scott Brandenburg	Hubert Deaton	Nima Goudarzi
Mark Breitnauer	Nariman Dehghani	Russell Green
Tracy Brettmann	J.T. DeJong	Phillip Gregory
Aaron Budge	Joel Dellaria	Shawn Griffiths
Mike Burlingame	Jerry DiMaggio	Nenad Gucunski
Susan Burns	Morris Dirnberger	Anasua GuhaRay
Ashly Cabas	Vishnu Diyaljee	Ranjiv Guptha
Allen Cadden	Jinung Do	Angel Gutierrez
James Carlton	Shaoyang Dong	Michael Haggerty
Wystan Carswell	Simon Dumais	Jim Hambleton
Bora Cetin	Elizabeth Dwyre	Jie Han
Halil Ceylan	Chadi El Mohtar	Adel Hanna
Minsu Cha	Usama El Shamy	Seddigheh Hasanpour
Ilhan Chang	Ghada Ellithy	Estahbanati
Jairaj Channshetty	Fathey Elsaïd	Ryan Haskins
Shunyi. C. Chen	Omar Elshafee	Ahmadreza Hedayat
Dar-Hao Chen	Shawwna Erter	Dennis Hiltunen
Xingwei Chen	Alan Esser	Tasha Hodges
Shengli Chen	Jongwan Eun	Megan Hoppe
Yanni Chen	Jeff Evans	Arash Hosseini
Qiushi Chen	Matt Evans	Isaac Howard
Bhaskar Chittoori	Ron Farmer	Laureano Hoyos
Andrew Cho	Saman Farzi Sizkow	Roman Hryciw
Kush Chohan	Aria Fathi	Liangbo Hu
Abhijeet Chordia	Bryan Field	Pao-Tsung Huang
Deepankar Choudhury	keyvan Fotoohi	Jonathan Hubler
Liang Chern Chow	Kevin Foye	Nick Hudyma
Jian Chu	Ray Franz	Jie Hunag
Cagri Cinkilic	Dante Fratta	Nejan Huvaj
Jose Clemente	Steve Gale	Kaoru Ikuma
Joseph Coe	Aaron Gallant	Amin Iraj
Travis Coleman	Carlos Garcia	Elvis Ishimwe
Surya Sarat Chandra	Luis Garcia	Md Touhidul Islam
Congress	Sarah Gassman	Nathan Iverson
Ivan Contreras	Hande Gerkus	John Ivoke

Robert Jaeger	Hai Lin	Shadi Najjar
Navid Jafari	Bret Lingwall	Anastasia Nally
Pegah Jarast	Qianwen Liu	Soonkie Nam
Sanjay Jha	Jose Lizarraga	Ataollah Nateghi
Zhefei Jin	Richard Lo	Kam Ng
Lawrence F. Johnsen	Erik Loehr	Trung Ngo
Sarah Johnson	John Lostumbo	Thanh Nguyen
Allen Jones	BK Low	Zhangwei Ning
Raviteja KVNS	Ning Lu	Masoud Nobahar
Edward Kavazanjian	Barbara Luke	Ozgun Numanoglu
Jeff Keaton	Jerry Luo	Chukwuebuka Nweke
Sadik Khan	Robert L. Lytton	Hyunjun Oh
Hamed Khodadadi	Nick Machairas	Scott Olson
Sara Khoshnevisan	Bob Mackey	Steve Olson
Ali Khosravi	Scott Mackiewicz	Thomas Oommen
Mahsa Khosrojerdi	Pooneh Maghoul	Abdolreza Osouli
Sunghwan Kim	Dan Mahrt	Thomas Pabst
Seunghee Kim	Roman Makhnenko	Adam Paisley
Yota Kokkali	Michael Mamlouk	Miguel Pando
Sreevalsa Kolathayar	Kalehiwot Manahiloh	Bruna Paranhos
Prabir Kolay	Majid Manzari	Ujwalkumar Patil
Tzvetomir Kotzev	Kimberly Martin	Menzer Pehlivan
Stacey Kulesza	Alejandro Martinez	Bijan Peik
Arvind Kumbhojkar	Brian Martinez	Tom Pennington
Wing Shun Kwan	Camilo Marulandan	Dunja Peric
Jay Kwon	Karen Masterson	Ryan Petersen
Joseph Labuz	Justice Maswoswe	Brandon Phetteplace
Debra Laefer	Ryan Maw	Carmine Polito
Rakam LamaTamang	John McCartney	Mihail Popescu
Richard Lamb	Jay McKelvey	Daniel Pradel
Mary Ellen Large	Roger Meier	Avinash Prasad
Nima Latifi	Farn-yuh Menq	Rafael Prieto
William Lawson	Fran Miller	Anand Puppala
Seung Jae Lee	Gerald Miller	Yujie Qi
Hyunjin Lee	Mohammadreza Mir	Parishad Rahbari
Ryan Leigh	Tamizdoust	Salman Rahimi
Ben Leshchinsky	Morteza Mirshekari	Mehrzaad Rahimi
Michael Lewis	Rozbeh Moghaddam	Md Mostaqur Rahman
Qiang Li	Arif Ali Baig Moghal	Shivani Rani
Jiliang Li	Rigoberto Moncada	Frank Rausche
Lin Li	Brina Montoya	Nadarajah Ravichandran
Kun Li	Sayedmasoud Mousavi	Krishna Reddy
Jia Li	Balasingam Muhunthan	Richard Regueiro
Xiang Li	Erik Muller	Greg Reuter
Willie Liew	Muralee Muraleetharan	Dan Rich
Garland Likins	Ashkan Nafisi	Seth Robertson

Brent Robinson	Pranshoo Solanki	Eric Wang
Carlos Rodriguez	Moataz Soliman	Lei Wang
Brahian Roman	Suji Somasundaram	Mark Wayne
Wenyong Rong	Xiaoyu Song	Lei Wei
Brent Rosenblad	Nina Stark	Andrea Welker
Jason Ross	Eric Steward	Haifang Wen
Alessandro F. Rotta Loria	Jeremy Stone	Joseph Westphal
Cholachat Rujikiatkamjorn	Bryan Strohman	Ben White
Cassandra Rutherford	Armin Stuedlein	Katherine Winters
Bassam Saad	Robert Swan	Kord Wissmann
Steve Saboundjian	Joel Swenson	Jeong Yun Won
Salah Sadek	Dave Sykora	Mike Wongkaew
David Saftner	Alireza Tabarsa	Timothy Wood
Rajni Saggu	Takefumi Takuma	Clint Wood
Mehmet Sagnak	Nagasreenivasu Talluri	Mark Woodward
Sajjad Salam	Prajwol Tamrakar	Chuangzhou Wu
Kristin Sample Lord	Julian Tao	Shifan Wu
Marcelo Sanchez	Oliver Taylor	Yuanjie Xiao
Brian Sanchez	Dimitrios Terzis	Ming Xiao
Debojit Sarker	Ed Theinat	Qinghao Yang
Sajjad Satvati	Brent Theroux	Alireza Yaseri
Vern Schaefer	Marlon Thomas	Alba Yerro-Colom
James Schneider	James Tinjum	Daryoush Yousefi Kebria
Montgomery Schultz	Binod Tiwari	Xinbao Yu
Karl Schwartz	Ingrid Tomac	Xiong Yu
Lois Schwarz	Hoang-Hung Tran-Nguyen	Atefeh Zamani
George Segré	Matthew Turner	Siavash Zamiran
Allen Sehn	Erol Tutumluer	Dimitrios Zekkos
Hoyoung Seo	Farshid Vahedifard	Limin Zhang
Jack Seto	Leon van Paassen	Yang Zhang
Ghassan Shahin	Dan VandenBerge	Bo Zhang
Radhey Sharma	Sotirios Vardakos	Ming Zhang
Ajay Shastri	Kalaiarasi Vembu	Xiong Zhang
Thevachandran Shenthan	Pavana Vennapusa	Lianyang Zhang
Scott Shewbridge	Gerald Verbeek	Yao Zhang
Xiang Shu	Cumaraswamy	Yi Zhao
Dawn Shuttle	Vipulanandan	Wenbin Zhao
Erin Sibley	Antonios Vytiniotis	Junxing Zheng
Lyle Simonton	Lucas Walshire	Cheng Zhu
Jon Sinnreich	Jakob Walter	Katerina Ziotopoulou
Jakub Skodowski	Corrie Walton-Macaulay	Jorge Zornberg