

IFCEE 2021

GSP 323

Installation, Testing, and Analysis of Deep Foundations

Selected Papers from the
International Foundation Congress and Equipment Expo 2021
Dallas, Texas ■ May 10–14, 2021

Edited by

Chadi El Mohtar, Ph.D.;
Stacey Kulesza, Ph.D.; Tugce Baser, Ph.D.;

13th International Foundation Congress and Equipment Expo



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

GEOTECHNICAL SPECIAL PUBLICATION NO. 323

IFCEE 2021

INSTALLATION, TESTING, AND ANALYSIS OF DEEP FOUNDATIONS

SELECTED PAPERS FROM SESSIONS OF THE INTERNATIONAL
FOUNDATIONS CONGRESS AND EQUIPMENT EXPO 2021

May 10–14, 2021
Dallas, Texas

SPONSORED BY
International Association of Foundation Drilling
Deep Foundations Institute
Pile Driving Contractors Association
The Geo-Institute of the
American Society of Civil Engineers

EDITED BY
Chadi El Mohtar, Ph.D.
Stacey Kulesza, Ph.D.
Tugce Baser, Ph.D.
Michael D. Venezia, 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/10.1061/9780784483404>

Copyright © 2021 by the American Society of Civil Engineers.
All Rights Reserved.
ISBN 978-0-7844-8340-4 (PDF)
Manufactured in the United States of America.

Preface

This is the first volume of four Geotechnical Special Publications (GSPs) containing papers from the 2021 International Foundations Congress and Equipment Expo (IFCEE21) held in Dallas, Texas on May 5–10, 2021. This volume includes a wide variety of topics that can generally be split into two collections: 1) Piles, Shafts & Load-Bearing elements, and 2) Deep Foundations. The first collection incorporates papers pertaining to varying types of deep foundation elements. The second collection of papers features topics related to engineering design, numerical analyses, load transfer mechanisms, LRFD, NDT, and thermal & energy aspects associated with deep foundation elements. The IFCEE conference series combines a technical conference and equipment show dedicated to the design and construction of foundation systems, using the latest geoengineering and geoconstruction technologies and practices. The IFCEE conference series is a one of a kind event that attracts attendees from around the world for the world's largest equipment exposition dedicated solely to the deep foundations industry. This Congress combined the 2021 annual meetings of ASCE's Geo-Institute, the International Association of Foundation Drilling (ADSC), the Pile Driving Contractors Association (PDCA) and the Deep Foundations Institute (DFI). This event was the fourth Congress in the IFCEE conference series, following the successful 2009, 2015, and 2018 meetings, in which these leading geotechnical and geotechnical-related organizations joined together for a single and singular annual congress. IFCEE'21 provided an international forum despite the unusual times to discuss technological advances, case histories, and present challenges and emerging topics related to geotechnical and foundation engineering. The congress was attended by a wide range of geo-professionals including engineers, contractors, academicians, equipment manufacturers, geotechnologists, 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 IFCEE 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 189 accepted technical papers, that were presented in 36 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 year 2020 has opened a global outpouring for a change, exposing some of the most insidious elements of the health and societal regime to public examination. Despite the difficulties, the Editors worked hard with the members of the organization committee and session chairs closely. The Editors would like to express their appreciation for having been provided the opportunity to be a part of this Congress' organization, their sincere thanks to the numerous session chairs and reviewers, and they hope that these proceedings will be of use to the geotechnical engineering community for many years to come.

The Editors,

Chadi El Mohtar, Ph.D., M.ASCE, University of Texas at Austin

Stacey Kulesza, Ph.D., PE, M.ASCE, Kansas State University

Tugce Baser, Ph.D., A.M.ASCE, M.DFI, University of Illinois at Urbana-Champaign

Michael D. Venezia, P.E., M.ASCE, M.DFI, M.PDCA

Acknowledgments

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

IFCEE 2021 Conference Program Committee

Conference Chair

Muhannad T. Suleiman, Ph.D., Lehigh University

Technical Program Committee

Tracy T. Brettmann, P.E., D.GE, M.ASCE, A.H. Beck

Les Chernauskas, P.E., M.ASCE, Geosciences Testing and Research Inc.

Peggy Hagerty-Duffy, P.E., D.GE, ADSC

Mary Ellen Bruce Large, P.E., D.GE, Deep Foundations Institute

Anne Lemnitzer, Ph.D., P.E., A.M.ASCE, University of California, Irvine

Alec McGillivray, Ph.D., P.E., Precast Piling Technology

Morgan Nesmith, P.E., M.ASCE, Berkel

Helen Robinson, P.E., M.ASCE, GEI Consultants

Jeff Segar, P.E., S.E., Braun intertec

Anna Sellountou, Ph.D., P.E., Pile Dynamics

Proceedings Editors

Chadi El Mohtar, Ph.D., M.ASCE, University of Texas at Austin

Stacey Kulesza, Ph.D., PE, M.ASCE, Kansas State University

Tugce Baser, Ph.D., A.M.ASCE, M.DFI, University of Illinois at Urbana-Champaign

Michael D. Venezia, P.E., M.ASCE, M.DFI, M.PDCA

IFCEE Draft Round Reviewers

Mehdi Abbasi	Kamelia Atefi Monfared	Gretchen Bohnhoff
John Abdalkhani	Kleio Avrithi	Tommy Bounds
Yasser Abdelhamid	Paul Axtell	Reza Boushehri
Pramila Adhikari	Aditya Ayithi	Merve Gizem Bozkurt
Alireza Afshani	Alireza Ayoubian	Aaron Bradshaw
Shehab Agaiby	Britt Babcock	Scott Brandenburg
Sean Ahdi	Hossein Bahmyari	Tracy Brettmann
Reza Ahmadi Naghadeh	Mohamadtaqi Baqersad	Frederick (RICK) A. Brinker
Asif Ahmed	Matthew Barendse	Aaron Budge
Md Ahsanuzzaman	Tugce Baser	Jason Buenker
Idil Akin	Curt Basnett	Allen Cadden
Hossein Alimohammadi	Ryan Beemer	Jack Cadigan
Ryan Allin	Brahim Benhamida	Sean Campbell
Alaa Alsharaballi	Jonathan Bennett	Greg Canivan
Daniel Alzamora	Duane Bents	Ziming Cao
Zahra Amini	Juan Bernal	Nina Carney
Joram Amir	Christine Beyzaei	Lucas Carr
Mohsen Amirmojahedi	Aditya Bhatt	Bernardo Castellanos
Paul Andersen	Tejo Bheemasetti	Mark Champagne
Donald Anderson	Dale Biggers	Leroy Chan
Nadir Ansari	Kedar Birid	Ilhan Chang
Mona Anwar	Thomas Bjartmarz	Yuyan Chen
Pouyan Asem	William Black	Shi-Chieh Cheng
Mohammed Ashfaq	Andrew Boeckmann	Les Chernauskas

Bhaskar Chittoori	Jongwan Eun	Jared Green
Gye-Chun Cho	Matt Evans	Garry Gregory
Alek Chongris	Fawzy Ezzein	John Grillo
Liang Chern Chow	Zahra Faeli	Donald Hagerty
Andrew Ciania	Zachary Fallert	Peggy Hagerty-Duffy
Jose Clemente	Ray Fassett	Jim Hambleton
Travis Coleman	Sixto Fernandez	Seth Hamblin
Brady Cox	Michael Flanagan	Nasser Hamdan
Sheng Dai	Keyvan Fotoohi	Jie Han
Domenic D'Argenzio	Kevin Foye	Pat Hannigan
Biswajit Dasgupta	Rudolph Frizzi	Jim Hansen
Tayler Day	Andrew Fuggle	Md Haque
Ricardo de Abreu	Aaron Gallant	Mahsa Hedayati
Nariman Dehghani	Paolo Gazzarrini	Bernard Hertlein
Berk Demir	Hande Gerkus	Shaun Hevey
Aditya Deshmukh	Ismaail Ghaaowd	Chu Ho
Darren Diehm	Pegah Ghasemi	Amanda Hohner
Jinung Do	Omid Ghasemifare	A S M Fahad Hossain
Wenjun Dong	Majid Ghayoomi	Laureano Hoyos
John Edens	Shahin Ghazizadeh	Feng Huang
Chadi El Mohtar	Avishek Ghosh	Jonathan Hubler
Hesham El Naggar	Matt Glisson	Nick Hudyma
Usama El Shamy	Aaron Goldberg	Erin Hunter
Kirk Ellison	Michael G. Gomez	Mohamad Hussein
Alexander Erb	David Graham	Nejan Huvaj
Alan Esser	Mattias Grävare	Hannah Iezzoni

Ritesh Ingale	Tony Kiefer	Garland Likins
Amin Iraj	Hyunki Kim	William Likos
Kazi Moinul Islam	Meeok Kim	Hai Lin
Md Aminul Islam	Eric Kline	Guoming Lin
Md Azizul Islam	Dimitrios Konstantakos	Jiaojun Liu
Karam Jaradat	Alireza Kordjazi	Erik Loehr
Ningjun Jiang	Alexander Kormanos	Scott Mackiewicz
Allen Jones	Andy Kositsky	Ashley MacMillan
Mohammad Joshaghani	Tim Kovacs	Sai Anudeep Reddy Maddi
Bhargav Kumar K P	Tim Kovaks	Nariman Mahabadi
Raviteja K V N S	Mayooran Krishnathasan	Masrur Mahedi
James Kaklamanos	Hanumanth Kulkarni	Wael Mahmood
Peter Kandar	Prem Kumar	Michael Malusis
Thierno Kane	Wing Shun Kwan	Kalehiwot Manahiloh
Pourya Kargar	Debra Laefer	Shahed Manzur
Andrew Keene	Rakam LamaTamang	Alejandro Martinez
Amaneh Kenarsari	Junghwoon Lee	Mario Mauro
Siva Kesavan	Gang Lei	Paul Mayne
Majid Khabbazian	Anne Lemnitzer	Alec McGillivray
Taha Khalaff	Aaron Leopold	Michael McGuire
Yazen Khasawneh	Christopher Lewis	Naveen Meena
Hamed Khodadadi	Kun Li	Marc Miller
Sara Khoshnevisan	Marina Li	Richard Millet
Mohammad Khosravi	Jiliang LI	Kim Ming
Ali Khosravi	Robert Liang	Mohammadreza Mir
Mahsa Khosrojerdi	Willie Liew	Tamizdoust

Rozbeh Moghaddam	Ayşe Özdoğan Dolcek	Helen Robinson
Aly Mohammad	Srisothinathan Pakeetharan	Brent Robinson
Ahmed Mohammed	Dimitrios Palantzas	Kyle Rollins
Ali Morovatdar	Miguel Pando	Wenyong Rong
Sarah Morton	Walter Paniagua	Shahrazad Roshankhah
Ramin Motamed	Arun Parihar	Aaron Sacks
Diane Moug	Jorge Parra	Shahin Safavizadeh
Gray Mullins	Amanda Parry	Rajni Saggi
Ryan Murphy	Veniece Pearman-Green	Rodrigo Salgado
Boohyun Nam	Tom Pennington	Kwestan Salimi
Ali Nazari Tileki	James Pergues	Duraisamy Saravanathiiban
Saeedeh Naziri	James Phipps	Paul Sauco
Morgan NeSmith	George Piscsalko	Robert Saunders
Thang Nguyen	Mihail Popescu	Joseph Scalia
Thai Nguyen	Amir Poshnejad	Montgomery Schultz
Silas Nichols	Mehran Pourakbar	Jeff Segar
Masoud Nobahar	Avinash Prasad	Ahmed Senhaji
Ozgun Numanoglu	James Racine	Ali Shafiee
Ebuka Nweke	Parishad Rahbari	Maryam Shahbazi
William Oder	Salman Rahimi	Mahesh Sharma
Hyunjun Oh	Saidur Rahman	Xianda Shen
Kyle O'Hara	Saman Rashidyan	John Shoucair
Guney Olgun	Stephanie Robat	Shweta Shrestha
Kimball Olsen	Shane Robat	Nayyar Siddiki
Scott Olson	Don Robertson	Damian Siebert
Michael Owens	Seth Robertson	Tim Siegel

John Siekmeier	Michael Venezia	Justin Zarella
Samuel Singer	Gerald Verbeek	Yida Zhang
Joanna Smith	Osvaldo Vitali	Yang Zhang
Ashish Solanki	Antonios Vytiniotis	Bo Zhang
Moataz Soliman	Scott Walker	Yao Zhang
Hoda Soltani	Bill Walton	Yan Zhang
Nina Stark	Corrie Walton-Macaulay	Benchen Zhang
Daniel Stevenson	Jintai Wang	Yewei Zheng
Eric Steward	Mark Wayne	Cheng Zhu
Jeremy Stone	Gillian Williams	Katerina Ziotopoulou
Jewels Stover	Brian Wilson	
C. K. Su	Katherine Winters	
Robert Swan	Daniel Woeste	
Sonia Swift	Mike Wongkaew	
Konstantinos Syngros	Chris Woods	
Steve Szabo	Ruoyang Wu	
Gilbert Tallard	Mike Wysockey	
Nagasreenivasu Talluri	Shangzhi Xiao	
Chia tan	Yang Xiao	
Hui Tao	Guangchao Xing	
Julian Tao	Thamer Yacoub	
Masi Tavakol	Davood Yazdani Cherati	
Ed Theinat	Adam Yoda	
Amanda Toye	Luis Zambrano Cruzatty	
Adeleine Tran	Siavash Zamiran	
Leon van Paassen	Shahabeddin Zaregarizi	