

Geo-Congress 2023

GSP 339

Soil Improvement, Geoenvironmental, and Sustainability

Selected Papers from Geo-Congress 2023
Los Angeles, California • March 26–29, 2023

Edited by
Ellen Rathje, Ph.D., P.E.
Brina M. Montoya, Ph.D., P.E.
Mark H. Wayne, Ph.D., P.E.

ASCE
G-I ASCE GEO-INSTITUTE

GEOTECHNICAL SPECIAL PUBLICATION NO. 339

GEO-CONGRESS 2023

SOIL IMPROVEMENT, GEOENVIRONMENTAL, AND SUSTAINABILITY

SELECTED PAPERS FROM SESSIONS OF
GEO-CONGRESS 2023

March 26–29, 2023
Los Angeles, California

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

EDITED BY
Ellen Rathje, Ph.D., P.E.
Brina M. Montoya, Ph.D., P.E.
Mark H. Wayne, Ph.D., P.E.

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/10.1061/9780784484661**

Copyright © 2023 by the American Society of Civil Engineers.
All Rights Reserved.
ISBN 978-0-7844-8466-1 (PDF)
Manufactured in the United States of America.

Preface

This is the second volume of six Geotechnical Special Publications (GSPs) containing papers from the 2023 Geo-Congress: Sustainable Infrastructure Solutions from the Ground Up, held in Los Angeles, California on March 26–29, 2023. These six volumes contain over 350 contributions that span 22 topic areas of the ASCE Geo-Institute's standing technical committee as well as 11 special topics unique to Geo-Congress 2023.

This volume is focused on contributions to soil improvement, including the use of biogeotechnics to achieve improved soil performance, geoenvironmental engineering, and topics associated with sustainability.

This publication culminates two years of effort by the technical planning committee whose focus has been to continue the success of the previous Geo-Congress 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 more than 350 accepted technical papers, that were presented in a wide range of technical 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, their sincere thanks to the numerous session chairs and reviewers, and we hope that these proceedings will be of use to the geotechnical engineering community for many years to come.

The Editors,

Ellen Rathje, Ph.D., P.E., F.ASCE, University of Texas at Austin
Brina M. Montoya, Ph.D., P.E., M.ASCE, North Carolina State University
Mark H. Wayne, Ph.D., P.E., M.ASCE, Tensar International

© ASCE

Acknowledgments

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

2023 GeoCongress Conference Program Committee

Conference Chair
Yoga Chandran, Ph.D., P.E., M.ASCE

Technical Program Committee
Chair, Scott Brandenberg, Ph.D., P.E., M.ASCE
Beena Ajmera, Ph.D., P.E., M.ASCE
David Albus, P.E., M.ASCE
Daniel Alzamora, P.E., M.ASCE
Ben Leshchinsky, Ph.D., P.E., M.ASCE
John McCartney, Ph.D., P.E., F.ASCE
Amy Rechenmacher, Ph.D., P.E., M.ASCE
Lisa Star, Ph.D., P.E., M.ASCE

Proceedings Editors
Ellen Rathje, Ph.D., P.E., F.ASCE, University of Texas at Austin
Brina Montoya, Ph.D., P.E., M.ASCE, North Carolina State University
Mark Wayne, P.E., M.ASCE, Tensar

© ASCE

Contents

Carbon Footprint of Construction

Life Cycle Assessment of Root-Inspired Ground Anchors and Conventional Ground Anchors.....1
John A. Huntoon, Valerie M. Thomas, and J. David Frost

Biochar in Quick Clay Stabilization: Reducing Carbon Footprint and Improving Shear Strength 15
Stefan Ritter, Priscilla Paniagua, and Gerard Cornelissen

Bioashes and Steel Slag as Alternative Binders in Ground Improvement of Quick Clays.....25
Priscilla Paniagua, Stefan Ritter, Mari Moseid, and Gudny Okkenhaug

Analysis of Pervious Oyster Shell Habitat (POSH) Unit Effectiveness Using Computational Fluid Dynamics (CFD) and Field Observations 35
Lauren Cope, Jacob Waggoner, Hunter Mathews, Kelly J. Smith, and Raphael Crowley

Tunnel Boring Machine Crushed Limestone as a Cement Grout.....45
Turki Alokili, Muawia Dafalla, Ahmed Al-Mahbashi, Ahmed Alnuaim, and Eljunaid Mutaz

Design and Life Cycle Assessment of Retaining Wall with Used Foundry Sand as Backfill.....55
Ankit Kumar and Aditya Parihar

Potential on Carbon Dioxide Utilization to Improve Recycled Concrete Aggregates and Reduce Carbon Footprint.....64
Amin Hosseini Zadeh, Chris Hawkins, Jim Ball, Nate Harper, Jiong Hu, and Seunghee Kim

Carbon Emissions Quantification of Landfill Final Cover Systems 75
Rutuparna V. Joshi

Low-Density Cellular Concrete as a Sustainable Replacement for Granular Fills in Bridge Approaches.....85
Sundeep Inti and Victor M. Garcia

© ASCE

Geoenvironmental Engineering

Performance Prediction of Evapotranspiration (ET) Cover from Field Monitoring Results....96
Md. Jobair Bin Alam, Asif Ahmed, Naima Rahman, and Md. Sahadat Hossain

A Fully Coupled Thermo-Hydro-Mechanical Response of an Advanced Geothermal Energy Storage System in a Sedimentary Basin....105
Josiane Jello and Tugce Baser

Chemico-Osmotic Coefficients of Geosynthetic Clay Liners under Different Confinement Conditions....116
Francesco Mazzieri and D. Bernardo

Landfill Odor (Hydrogen Sulfide) Control Using Novel Biogeochemical Cover System....127
Jyoti K. Chetri and Krishna R. Reddy

Bioremediation of Salinity Problem by Using Collective Microorganisms in Semi-Aerobic Landfill....134
Azizul Moqsud

Effects of Leachate Recirculation Systems on Slope Stability of Bioreactor Landfills....141
Lagudu S. Avinash and Anumita Mishra

Performance of MICP-Treated Soil against Environmental Deterioration....152
Shihui Liu and Lin Li

Development of Cation Exchange Processes in Geosynthetic Clay Liners....162
Kurt D. Katzenberger, James L. Hanson, Nazli Yesiller, Kuo Tian, Dong Li, and Kristin Sample-Lord

Solute Diffusion through Bentonite-Polymer Composites for Containment Applications....171
Daniel Adeleke, Sayed Arafat B. Rahman, Victoria Chanez, Jenna Springer, Sarah Burghardt, Kristin Sample-Lord, Gretchen Bohnhoff, and Jonathan Hubler

Water Balance Final Cover Using Vetiver Grass in Texas....182
Sonia Samir and Mohammad S. Khan

Using Random Forest Algorithm to Predict the Hydraulic Conductivity of Compacted Soil Liners/Covers....193
Poyu Zhang, Yu Tan, Jiannan Chen, and Boo Hyun Nam

© ASCE

Climate Impacts of Trace Gas Emissions from Solid Waste Landfills 201
James L. Hanson, Derek C. Manheim, and Nazli Yeşiller

Biocarbon-Driven Remediation of Oil Contaminated Soils 211
Fei Wang, Daniel Martinez, and Jie Huang

Geoenvironmental Condition Improvement by Using Microbial Fuel Cell 219
Azizul Moqsud

Soil Improvement

Mechanical Behavior of MICP-Treated Sand under Different Confining Pressures 225
Junjie Li, Kejun Wen, Huang Wei, Lin Li, and Farshad Amini

Modelling of Stone Columns Reinforces Railway Embankments: Coupled DEM-FDM Analysis 235
Trung Ngo, Buddhima Indraratna, and Cholachat Rujikiatkamjorn

Cyclic Wetting and Drying Behaviour of Coal Wash Treated Black Soil 246
Courage Kwasi Dzaklo, Cholachat Rujikiatkamjorn, Buddhima Indraratna, and Richard Kelly

Instrumented Testing of Soft Clay Behaviors for the Savannah Container Terminal 255
Yan Jiang and Guoming Lin

Evaluation of Stabilization Concepts for Clay and Sandy Clay as Subgrade Material Using Cement and Liquid Base Seal 264
E. W. Gadzama, K. A. Kau, A. D. Talba, and K. J. Osinubi

Effect of Calcium Source on Sand Bio-Cementation 274
Yu-Syuan Jhuo, Hui-Ee Wong, and Louis Ge

Experimental Study on the Biopolymer Hydrogel Effect on Pile Driving Resistance 282
Mintae Kim, Suhyuk Park, and Ilhan Chang

The Importance of Partial Drainage in the Response of Soft Clays Reinforced with Sand Column Groups 289
Abdurrahman Almikati, Salah Sadek, and Shadi Najjar

The Impact of Biocalcification on Strength of Semi-Arid Zone Sand of Northeastern Nigeria 300
Kolawole J. Osinubi, Adrian O. Eberemu, Thomas S. Ijimdiya, and Mutiu A. Oyelakin

© ASCE

Dynamic Compaction: A Proven Ground Improvement Method for Landfill Sites **311**
Chris Woods, Robert Shaffer, and Samuel Drumheller

Study on Crosslink-Induced Gelation of Xanthan Gum Biopolymer and Its Soil Strengthening Behavior as Sustainable Grout Material **322**
Minhyeong Lee, Dong-Yeop Park, Yeong-Man Kwon, Ilhan Chang, and Gye-Chun Cho

Hydraulic Conductivity of Soil with Poly-Vinyl Alcohol (PVA) **331**
Kleio Avrithi, Marlo J. Mecredy, and Leila N. Kelly

Effectiveness of Microbial Induced Calcite Precipitation on Sand-Clay Mixtures **340**
Krishna Kumar, Joyprakash Naskar, and Anil Kumar Sharma

Evaluating Injection Strategies for Microbially Induced Calcite Precipitation and Implications for Applications to Road Structures **351**
Hudson Dorian, Pinar Gunyol, Jenna Lauf, Mohammad Khosravi, Adrienne Phillips, and Alfred Cunningham

Methods for Enhancing Uniformity of Biocementation Treatment in Sand **361**
Han-Jiang Lai, Ming-Juan Cui, Shi-Fan Wu, and Jian Chu

Influence of Compaction Characteristics and Moisture Exposure on Resilient Moduli of Cement-Treated Soil **370**
Prince Kumar, Anand J. Puppala, Surya Sarat Chandra Congress, Krishneswar Ramineni, and Jeb S. Tingle

Effect of Treatment Strategies for MICP-Based Soil Improvement Using Urease-Producing Bacteria **381**
Rituraj Devrani, Prashanth Vangla, and Shilpi Sharma

Shear Strength, Excess Pore Water Pressure, and Durability Response of Class F Fly Ash Treated with Hydrated Lime **391**
Sujay Teli and Ajanta Sachan

Improving the Effectivity of Dynamic Compaction Methods in Silty Sands through Microbial Induced Desaturation (MID) **402**
Michael T. Stals, Gustav Andrag, Bas Vos, and Leon A. van Paassen

A Novel Approach to Control Ice Formation with Psychrophilic Microbes **411**
Rashed Rahman, Tejo V. Bheemasetti, Tanvi Govil, Aditya Ticku, and Rajesh Sani

© ASCE

Reliability Analysis of Polyvinyl Alcohol Fiber-Reinforced Soft Subgrade Soil Treated with Lime and Alkali Activated Stabilizer: A Comparative Study 422
Mazhar Syed, Arif Ali Baig Moghal, and Bhaskar Chittoori

Investigation of the Biopolymer *Rhizobium tropici* for Use in Soil Improvement 433
Samantha Lucker, Lucas Walshire, Kuan-Che Feng, Maureen K. Corcoran, and Steven L. Larson

Durability and Recuperative Properties of Lime Stabilized Soils 440
Samridh, Aseem Jain, Sayantan Chakraborty, Nripojyoti Biswas, Anand J. Puppala, and Krishneswar Ramineni

Compaction and Strength Characteristics of Engineered Water Repellent Frost Susceptible Soils 452
Mackenzie Malisher, John Daniels, Micheal Uduebor, and Yunesh Saulick

Biopolymers for Erosion Mitigation of Soils Observed by Erosion Function Apparatus (EFA) 462
Yeong-Man Kwon, Minhyeong Lee, Ilhan Chang, and Gye-Chun Cho

Constant Curing Temperature Effect on the Strength of Cement-Treated Soil 470
Hwanik Ju, Roberto Nevárez-Garibaldi, Sherif L. Abdelaziz, and George M. Filz

Experimental Evaluation of Stress Path of Weak Foundation Soil Reinforced with Recycled Plastic Pins 479
Faria Fahim Badhon and Md. Azijul Islam

Use of Magnetic Field to Rotate Iron Filings in Sand as Means of Soil Improvement 490
Xinyi Jiang and Cassandra Rutherford

Direct Shear Tests of Sand Reinforced with Ferrous Particles 500
Xinyi Jiang and Cassandra Rutherford

Influence of Treatment Temperature Conditions on the Performance of Enzyme-Induced Cemented Sand 509
Isaac Ahenkorah, Md. Mizanur Rahman, Md. Rajibul Karim, and Simon Beecham

Negative Effect of Tannic Acid on the Strength of Cement-Stabilized Soil 520
Hwanik Ju, Sherif L. Abdelaziz, and George M. Filz

© ASCE

Effect of Exposure to Water at Different Temperatures during Curing on the Strength of Cement-Treated Soil.....529
Hwanik Ju, Sherif L. Abdelaziz, and George M. Filz

Non-Contact Measurement of Vertical Deflections of Rail Trackbeds and Performance Testing of Stabilized Sub-Ballasts Using a Novel Micropiling System.....539
Koohyar Faizi, Paul Beetham, Rolands Kromanis, and John Allsop

The Effect of Level of Cementation and Geometry on Stability of Cemented Coastal Bluffs and Slopes.....549
Pegah Ghasemi and Brina M. Montoya

Effect of Bio-Cementation on Drained Instability of Poorly Graded Sand with Sub-Angular Particle Shapes.....558
E. Yazdani, B. Montoya, and T. M. Evans

Sustainability in Geotechnical Engineering

Experimental Study of Rubber Intermixed Ballast Stratum Subjected to Monotonic and Cyclic Loads 565
Chathuri M. K. Arachchige, Buddhima Indraratna, Yujie Qi, and Cholachat Rujikiatkamjorn

Application of Tire Derived Aggregates in Seismic Response of Railway Embankments.....575
Arezoo Sadrinezhad and Merced Martinez

Review of Life Cycle Assessment (LCA) Evaluation of Geotechnical Systems.....583
Dora L. de Melo, Alissa Kendall, and Jason T. DeJong

Numerical Simulation of a Geothermal Bridge Deck Deicing System for Use in Montana 593
Ethan Turner, Kathryn Plymesser, Mohammad Khosravi, Kirsten Matteson, and Grant McNamara

Analyzing the Feasibility of Using Shallow Geothermal Energy to Prohibit Pavement Thermal Cracking: Field Testing.....603
Amin Mohammadzadeh, Fereydoun Najafian Jazi, Omid Ghasemi-Fare, and Zhihui Sun

Numerical Analysis of Hydraulic Conductivity Effect on the Utilization of Recycled Asphalt Pavement in Highway Design 612
Zorana Mijic, Mustafa Hatipoglu, Asli Y. Dayioglu, and Ahmet H. Aydilek

© ASCE

Soil-Stabilizing Potential of Using Food Industry Byproducts 622
Nicole Kelly and Arvin Farid

Sustainable Design, Equity, and Social Justice

Sustainability and the Road to Carbon Neutrality with Low-Density Cellular Concrete (LDCC) 632
Gregory Halsted and Nico Sutmoller

Nature-Based Solutions for Enhancing Soil Hydro-Mechanical Properties 640
Nawaf M. Alneami, Mathew Kubes, and Marta Miletic

Effect of Climate Change on Depth of Suction Change—A Case Study 649
Bikash Devkota, Md. Rajibul Karim, Md. Mizanur Rahman, Khoi Nguyen, and Asif Iqbal

Application of Environmental Product Declarations in Sustainability of Geotechnical Structures 661
Fariborz M. Tehrani

© ASCE

Life Cycle Assessment of Root-Inspired Ground Anchors and Conventional Ground Anchors

John A. Huntoon[1]; Valerie M. Thomas, Ph.D.[2]; and J. David Frost, Ph.D., P.E., P.Eng., F.ASCE[3]

[1]School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta, GA. Email: jhuntoon3@gatech.edu
[2]H. Milton Stewart School of Industrial and Systems Engineering, Georgia Institute of Technology, Atlanta, GA. Email: valerie.thomas@isye.gatech.edu
[3]School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta, GA. Email: david.frost@ce.gatech.edu

ABSTRACT

This paper presents the methodology and results of cradle-to-gate life cycle assessments (LCAs) performed for full-scale, root-inspired ground anchor (RIGA) prototypes, and conventional straight-shaft ground anchors (CGAs). LCAs performed in this study quantified the total environmental emissions of each ground anchor system in lb CO_2e emissions per anchor installed, for anchors anticipated to have equivalent ultimate capacities. Based on preliminary load-displacement pullout test results, comparison is made between a temporary 55-foot long CGA and a 38-foot-long RIGA. The CGA is estimated to emit 942 lb CO_2e, while the RIGA is estimated to emit 703 lb CO_2e per anchor, a 25% reduction. Material savings of 191 lb of cement and 28 lb of ferrous products per anchor are also expected. System boundary limits, manufacturing process assumptions, and assessment implications are discussed.

INTRODUCTION

Conventional ground anchors (CGAs) generally consist of a long steel tendon placed in a pre-drilled hole in the ground surface and then encased in cement grout, forming an approximately cylindrical grout element with a protruding steel head that is connected to the rest of the structure. Root-Inspired Ground Anchors (RIGAs) attempt to incorporate the geometry of fibrous plant roots into a ground anchor for human infrastructure with the potential benefits of decreased required bond length and/or increased anchor capacity. Previous publications describe the form, installation process, and ultimate capacity expectations of plant root-inspired ground anchors in greater detail (Mallett, 2019 [35], Mallett et al., 2021 [36], Huntoon et al., 2022 [31]). Based on preliminary load-displacement pullout test results by Huntoon et al. [31], this paper presents comparative Life Cycle Assessments (LCAs) for, and a LCA comparison between, a temporary 55-foot-long CGA and a hypothesized, functionally equivalent 38-foot-long RIGA, a reduction in bonded length made possible by the observed 75% increase in apparent bond strength for the RIGA over the CGA [31].

Since the materials and equipment used to install both anchor types are similar, equivalent carbon dioxide emissions (CO_2e) was selected as the metric by which to compare the impact of each system, referred to herein as "emissions". Additional relevant environmental impacts exist which are not captured by this metric nor considered in this study. Preliminary life cycle inventory estimates using the U.S. Life Cycle Inventory Database indicated that the significant contributors to the equivalent CO_2 emissions of each system are, in descending order, cement

© ASCE

grout production, ferrous component production, installation equipment operation, and plastic production [39]. The significance and evaluation methodology for each of these components will be addressed in this order and will also include transportation of workers and materials to a jobsite and miscellaneous contributors. The cradle-to-gate system boundary used in this LCA is shown in Figure 1. This boundary excludes equipment manufacturing, personnel training, and potential anchor recycling.

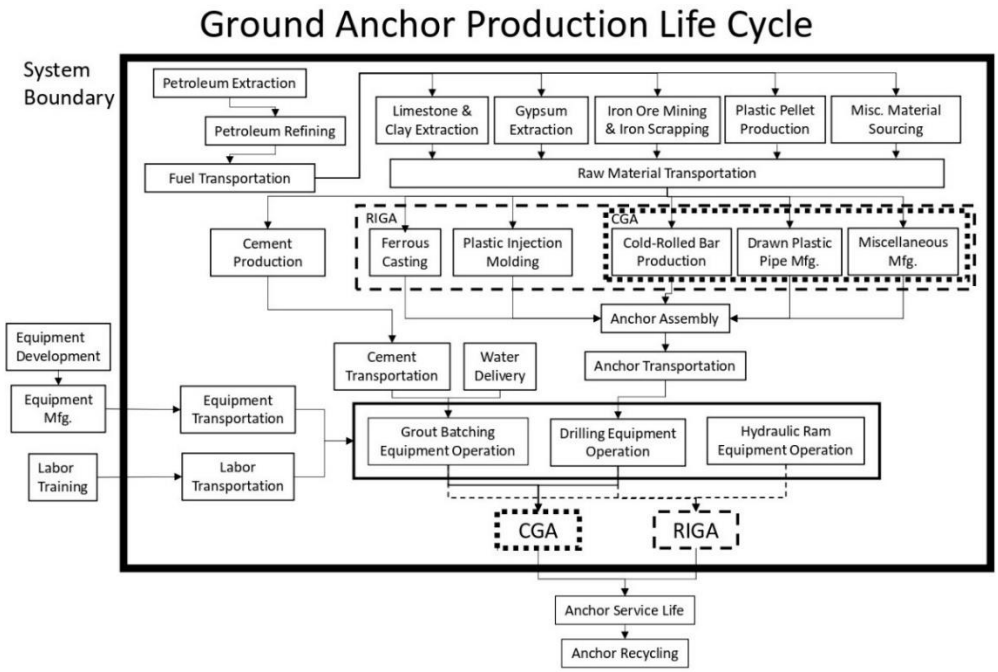


Figure 1. LCA System Boundary.

CEMENT GROUT PRODUCTION

Cement grout is created by combining powdered cement and water into a slurry mixture. This mixture can easily be pumped or placed in difficult to access areas and can permeate through small openings.

Cement Production. Cement production begins with the extraction and transportation of mineral resources from the earth, typically limestone, clay, and gypsum. During production, limestone and clay are crushed then fired in a cement kiln where they undergo chemical changes and become clinker. This process emits CO_2 and other products in two ways: the firing process itself requires combustion, which releases CO_2, and the heat inside the kiln causes the clinker constituents to undergo a chemical reaction which releases CO_2 [4][6][27]. Once fired, clinker is further ground and combined with gypsum, which acts as a retarder [9][25]. This combination is known as cement and is shipped from the plant. The US EPA reports the direct CO_2 emissions of US cement kilns to be 0.776 lb. CO_2 per lb. cement produced, as of 2019 [68]. An estimated 0.024 lb. CO_2e per lb. cement are generated by raw material extraction and transportation to the cement plant [4][9].

Cement Transportation. Cement is a heavy product with a bulk density of approximately 94 lb. per cf. and is typically transported as a dry bulk good from one of 97 cement production

© ASCE