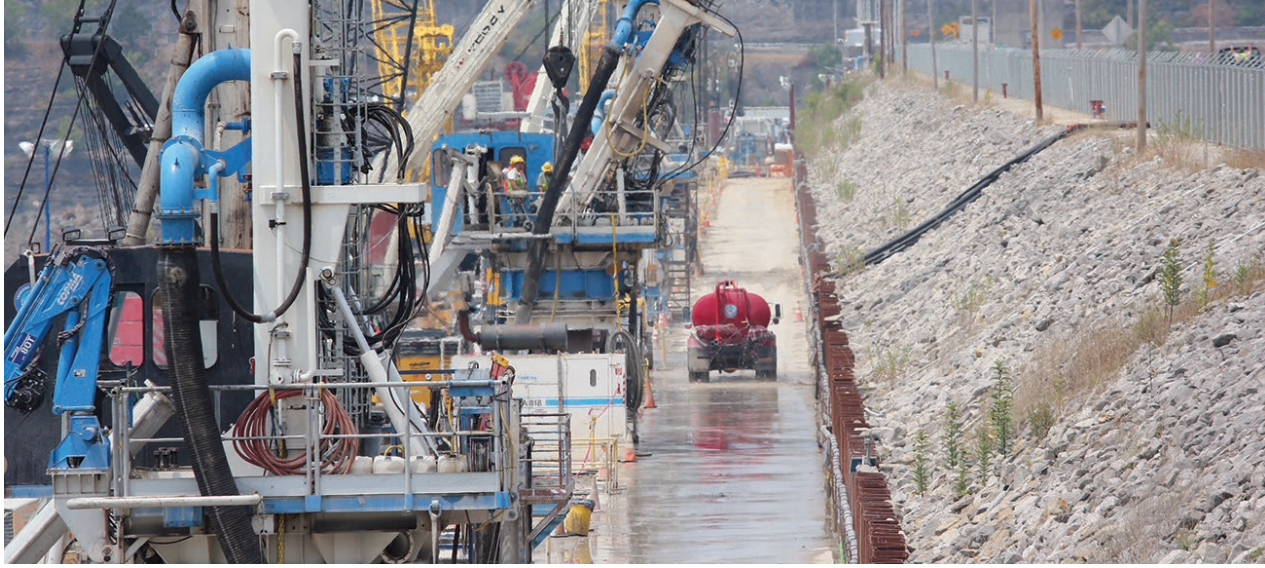


Grouting 2017

Jet Grouting, Diaphragm Walls, and Deep Mixing

GSP 289





Papers from Sessions of
Grouting 2017:
Grouting, Deep Mixing,
and Diaphragm Walls

July 9–12, 2017
Honolulu, Hawaii

Edited by

Paolo Gazzarrini, P.Eng.; Thomas D. Richards Jr., P.E., D.GE;
Donald A. Bruce, Ph.D., C.Eng., D.GE;
Michael J. Byle, P.E., D.GE; Chadi S. El Mohtar, Ph.D.;
and Lawrence F. Johnsen, P.E., D.GE

ASCE

G-I GEO-INSTITUTE

GEOTECHNICAL SPECIAL PUBLICATION NO. 289

GROUTING 2017

JET GROUTING, DIAPHRAGM WALLS, AND DEEP MIXING

SELECTED PAPERS FROM SESSIONS OF
GROUTING 2017

July 9–12, 2017
Honolulu, Hawaii

SPONSORED BY

International Conference Organization for Grouting (ICOG)

Geo-Institute of the American Society of Civil Engineers

EDITED BY
Paolo Gazzarrini, P.Eng.
Thomas D. Richards Jr., P.E., D.GE
Donald A. Bruce, Ph.D., C.Eng., D.GE
Michael J. Byle, P.E., D.GE
Chadi S. El Mohtar, Ph.D.
Lawrence F. Johnsen, P.E., D.GE

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/10.1061/9780784480809

Copyright © 2017 by the American Society of Civil Engineers.
All Rights Reserved.
ISBN 978-0-7844-8080-9 (PDF)
Manufactured in the United States of America.

Preface

This is the third Geotechnical Special Publication of the proceedings of Grouting 2017, the Fifth International Conference on Grouting, Deep Mixing, and Diaphragm Walls held in Honolulu Hawaii, U.S.A. July 9-12, 2017. Grouting 2017 is the fifth in a series of international conferences that began in 1982 to advance the science and technology of grouting, and these proceedings represent a five-year update from the previous conference in 2012 New Orleans.

The three GSPs of these proceedings capture 1) advances in the technology of materials, instrumentation, control, and the basic science of grouting, deep mixing and diaphragm walls that will lead to new and deeper understanding, new applications, and directions for the future; 2) exciting new information on Grouting and Deep Mixing practices for monitoring and instrumentation technology that is becoming the new normal for these technologies throughout the world; and 3) new integration of multiple technologies for diaphragm wall construction and remediation.

GSP 289 concentrates on Jet Grouting, Deep Mixing Methods, and Diaphragm Walls with papers focusing on control, verification, and/or innovation. Very interesting case histories on dam cut-offs, excavation support, general soil improvement, and tunneling are included in this volume, highlighting the constant research being carried out in the grouting industry, including innovation and varying approaches for production and verification.

These proceedings have been produced thanks to international support of numerous organizations and individuals, including the: ASCE, Geo-Institute of ASCE, US DOT FHWA, Deep Foundations Institute, and International Conference Organization for Grouting (ICOG). This publication culminates two years of effort by the planning committee whose focus has been to continue the vision established in the initial conference chaired by Wallace Hayward Baker and to keep the proceedings of this conference as the definitive source of information on the cutting edge of grouting and related technologies. 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. 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 previous four conferences held in 1982, 1992, 2003, and 2012 were organized by the Grouting Committee of the ASCE/Geo-Institute and ICOG. ICOG is an independent organization that arose from the Grouting Committee of the Geo-Institute with the purpose of promoting the continuing growth of the understanding and use of geotechnical grouting. ICOG has worked closely with the Geo-Institute in the organization of this conference and preparation of these proceedings.

© ASCE

Acknowledgments

The success of The Fifth International Conference on Grouting depended on numerous individuals as well as the legacy of this series of international grouting conferences, all of which have been organized by the Geo-Institute of ASCE's Grouting Technical Committee. The first international conference in 1982 was the brainchild of Wally Baker.

Thanks are due to the authors, reviewers, program committee, technical advisory committee, session chairs, moderators, sponsors, exhibitors, attendees and the ASCE conference organizing committee, notably Helen Cook and Brad Keelor.

Grouting 2017 Program Committee

Conference Chair: Michael J. Byle, P.E., D.GE, F.ASCE; Tetra Tech, Inc.
Conference Co-Chair: Lawrence F. Johnsen, P.E., D.GE, M.ASCE; GZA GeoEnvironmental, Inc.
Conference Co-Chair: Paolo Gazzarrini, P.Eng, M.ASCE; Sea to Sky Geotech Inc.
Conference Co-Chair and Workshops Co-Chair: Donald A. Bruce, Ph.D., D.GE, M.ASCE; Geosystems L.P.
Technical Program Co-Chair: Allen Cadden, P.E., D.GE, F.ASCE; Schnabel Engineering

Committee Members
Samson W. Bandimere, Aff.M.ASCE; Bandimere Grouting Consulting Services
Michael J. Miluski, P.E., M.ASCE; Compaction Grouting Services, Inc.
George K. Burke, P.E., D.GE, M.ASCE; Hayward Baker, Inc.
Joe Harris, Aff.M.ASCE; Hayward Baker, Inc.
Steve C. Maranowski, A.M.ASCE; Spartan Specialties Ltd.
Daniel Bole, A.M.ASCE; Hayward Baker, Inc.
Thomas D. Richards, Jr., P.E., D.GE, M.ASCE; Nicholson Construction Company
Justice J. Maswoswe, Ph.D., P.E., M.ASCE; FHWA Resource Center
Cumaraswamy "Vipu" Vipulanandan, Ph.D., P.E., M.ASCE; University of Houston
Chadi El Mohtar, Ph.D., A.M.ASCE; University of Texas at Austin
Reyn Shyo Hashiro, P.E., M.ASCE; Yogi Kwong Engineering LLC
Francis B. Gularte, M.ASCE; Hayward Baker, Inc.
James Warner, F.ASCE; Independent Consultant

Technical Advisory Committee
Australia — Ernst Friedlaender, *Keller Ground Engineering Pty Ltd*
Austria — Professor Scott Kieffer, *Graz University of Technology*
Brazil — Arsenio Negro, *Bureau de Projetos*
Canada —Paolo Gazzarrini, *Sea to Sky Geotech Inc.*
Italy — Giuseppe A. Modoni, *University of Cassino*
Japan — Masaaki Terashi, *Independent Consultant*
Morocco — Ahmed F. Chraibi, *DAMTECH*

© ASCE

Poland — Michal Topolnicki, *Keller Polska*
Sweden — Ulf Bertil Hakansson, *Skanska AB*
Sweden — Goran Hol, *Swedish Geotechnical Institute*
Switzerland — Katterbach Maren, *Lombardi Consulting Engineers Ltd.*
Thailand — Dennes T. Bergado, *Asian Institute of Technology*
United Kingdom — Stephan Jefferis, *Environmental Geotechnics Limited, University of Oxford St. Mary's Grove*
United Kingdom — Clif Kettle, *Bachy Soletanche Limited*
USA — Jie Han, *University of Kansas*

Grouting 2017 Session Chairs

TRACK 1/ Diaphragm Walls
1A0/ Design and Assessment
1B0/ Construction and Innovation
1C0/ Verification, QA/QC
1D0/ Case Histories
- Thomas D. Richards, Jr., P.E., D.GE, M.ASCE, *Nicholson Construction Company*

TRACK 2/ Deep Mixing
2A0/ Design and Assessment
2B0/ Construction and Innovation
2C0/ Verification, QA/QC
2D0/ Case Histories
- Donald A. Bruce, Ph.D., D.GE, M.ASCE; *Geosystems L.P.*

TRACK 3/ Drilling and Grouting
3A0/ Design and Assessment
- Chadi El Mohtar, Ph.D., A.M.ASCE, *University of Texas at Austin*
- Lisheng Shao, Ph.D., P.E., G.E., M.ASCE, *Hayward Baker Inc.*

3B0/ Construction and Innovation
3B1/ Bio-Treatment
- Chadi El Mohtar, Ph.D., A.M.ASCE, *University of Texas at Austin*

3C0/ Verification, QA/QC
- Michael J. Miluski, P.E., M.ASCE; *Compaction Grouting Services, Inc.*

3D1/ Case Histories: Karst
- Michael J. Byle, P.E., D.GE, F.ASCE; *Tetra Tech, Inc.*

3D2/ Case Histories: Piles and Anchors
- Peter Bowman, *Advanced Construction Techniques Ltd.*

3D3/ Case Histories: Jet Grouting
- Paolo Gazzarrini, P.Eng, M.ASCE; Sea to Sky Geotech Inc.

© ASCE

3D4/ Case Histories: Other

- Lawrence F. Johnsen, P.E., D.GE, M.ASCE; GZA GeoEnvironmental, Inc.
- Walter E. Kaeck, P.E., M.ASCE, Mueser Rutledge Consulting Engineers
- Alan R. Ringen, P.E., M.ASCE, Hayward Baker Inc.

Grouting 2017 Paper Reviewers

Andy Anderson
Tim Avery
Ali Azizian
Nicholas Bachand
David Barstow
Vanesa Bateman
Diego Bellato
Rachael Bisnett
Robert Bivens
Robert Bliss
Adriane Boscardin
Marco Boscardin
Peter Bowman
Eric Bregman
Donald Bruce
George Burke
Michael Byle
Joanna Bzowka
Allen Cadden
Swami Charan
King Chin
Pierre Choquet
Michael Chow
Paddy Cochran
Todd Culp
Thomas Dalmalm
James Davies
James Davis
Jason DeJong
Chadi El Mohtar
Magnus Eriksson
Jeffrey Evans
Bob Faulhaber
Alessandro Flora
Gary Fuerstenberg
Johan Funehag
Paolo Gazzarrini
Franz-Werner Gerressen
Glen Gorski
Clay Griffin
Francis Gularte
Ron Hall
Seth Hamblin
Mark Hampton
Joe Harris
Doug Heenan
Olivier Helson
Raymond Henn
Georgette Hlepas
Chu Ho
William Hover
Siu-Wang Huang
Ken Ivanetich
Hamza Jaffal
Jon Jagello
Mike Jefferies
Stephan Jefferis
Lawrence Johnsen
Walter Kaeck
Edward Kavazanjian
Hamed Khodadadi
Jack Kinley
Kazuhiko Komatsu
Takao Kono
Sara Kvartsberg
James Kwong
Eric Landry
Paul Lewis
Marina Li
Vittorio Manassero
Steve Maranowski
Roman Marte

© ASCE

Justice Maswoswe
Fabrice Mathieu
Nabil Mikhail
Michael Miluski
Giuseppe Modoni
Matthew Morris
Kabilan Nagappan
Tsutomu Namikawa
Luigi Narduzzo
Ward Naudts
Binh Nguyen
Matthew Niermann
Seth Olsen
Yoshinori (Jimmy) Oshiro
Giuseppe Panetta
Ignazio Paolo Marzano
Dominic Parmaniter
Joseph Pastore
Juan Pestana
Andy Peterson
Ananth Ramasamy
Alan Rauch
Thomas Richards, Jr.
Alan Ringen
Piero Roberti
Bradford Roberts
Ritika Sangroya
Paul Schmall
Wesley Schmutzler
Joern Seitz
Maurizio Siepi
Joseph Sopko
Daniel Stare
Kenneth Stokoe, II
Federico Stucchi
Rakam Tamang
Matthew Taylor
Hoang-Hung Tran-Nguyen
Tsutomu Tsuchiya
Rasim Tumer
Leon Van Paassen
Cumaraswamy Vipulanandan
James Warner
Cassandra Wetzel
Peter Wilén
Brian Wilson
Michael Xu
Justin Zarrella
Magnus Zetterlund

© ASCE

Contents

Jet Grouting: New Shapes and Applications

Development of the MultiFan-Shaped Jet Grouting Method of Ground Improvement 1
Takashi Shinsaka, Junichi Yamazaki, Yasuharu Nakanishi, and Kazuhito Komiya

Elliptical Jet Grouting: An Innovative, Viable, and Effective Solution: The Example of the Bottom Plugs for the SELA Projects in New Orleans, LA 11
Filippo Maria Leoni and Gianluca Pianezze

A Study on Altering the Cross-Sectional Shape and Altering the Quality of the Jet Grout Column 21
T. Tsutomu, A. Hiroyuki, and K. Kazuhiko

An Unconventional Application of Jet Grouting to Install 4900 kN Ground Anchors in Loose Alluvial Soil 31
Vittorio Manassero

Jet Grouting: Verification and Testing

Assessment of Jet Grout Column Diameter during Construction Using Electrical Resistivity Imaging 42
Michael A. Mooney and Richard G. Bearce

Experimental Evidence on the Strength of Soil Treated with Single and Double Fluid Jet Grouting 52
L. Wanik, M. C. Masaccio, J. Bzówka, G. Modoni, and J. S. L. Shen

Mechanical Behaviors of Soilcrete Created from Soils of Tam Bang and Vam Dinh Bridges Simulating Jet Grouting Technology 62
Hoang-Hung Tran-Nguyen and Chuong Hong Quach

Quantitative Interpretation of Surface Wave Testing for Assessment of Ground Improvement by Jet Grouting 73
Chih-Ping Lin, Chun-Hung Lin, Yu-Cheng Chang, and Chih-Jung Chien

Uplift Control of Jet Grouted Bottom Plug by Friction Mobilized along Embedded Anchoring Elements 82
Michał Topolnicki

© ASCE

Jet Grouting: Case Histories

Construction of a Jet-Grouted Backup Seepage Cut-Off Wall in the John Hart North Earthfill Dam.....92
Paolo Gazzarrini, David Siu, and Stephen Jungaro

Dewatering Dike Construction and Grouting at the Meadowbank Mine, Northern Canada 102
Vafa T. Rombough, Grant R. Bonin, Fiona Esford, and Michel R. Julien

Jet-Grouting as Earth Retention System in the Canadian Pacific Northwest: Case History of a Challenging 16 Meter Deep Excavation.....114
Paolo Gazzarrini, Matt Kokan, Stephen Jungaro, and Dan Hunt

Jet Grouting for Water Cutoff and Excavation Support.....124
Matthew J. Niermann, Douglas R. Jenevein, and Stanley L. Worst

Jet Grouting within Contaminated Land Fill 135
Camille Debost, Fabrice Mathieu, and Murray Yates

Jet Grouting within Toronto's Glacial Deposits, a Contractor's Perspective.....145
Yves St-Amour, Lucie Clatworthy, and Masoud Manzari

Overcoming Grouting Difficulties during Retaining Wall Stabilization.....155
Jared M. Green and Alan R. Poeppel

Rehabilitative Grouting for the Anacostia River Tunnel 165
Paul C. Schmall, James C. Myers, Lucian P. Spiteri, and Stephen D. Hawkins

The State of Jet Grouting in North America: Where We Are and Where It Is Practical 175
George K. Burke, Kenneth Ivanetich, and Timothy Myers

Use of Jet Grouting in Retrofitting of a RMG Factory Building in Chittagong, Bangladesh 186
Hamidul Ahasan, Shajal Khan, Ahmedul Hassan, Raquib Ahsan, and Mehedi Ahmed Ansary

Deep Mixing

Assessment of Key Properties of Solidified Fly Ash with and without Sodium Sulfate 197
J. C. Evans, G. P. Piuzzi, and D. G. Ruffing

© ASCE

Cased-Pipe Sampling for Quality Assurance of Deep Mixing Method: A Case Study 207
Ignazio Paolo Marzano, Massimo Grisolia, Giuseppe Iorio, Giuseppe Panetta, and Raffaele Papa

Cement-Bentonite Slurry Walls for Seismic Containment of the Kingston Coal Ash Landfill 216
Alan F. Rauch, Steve Artman, John C. Kammeyer, Bruce J. Haas, Jeffrey Barrett, Tom Pace, P. Bradford Smiley, Michael J. Steele, and Yong Wu

Centrifuge Model Studies on External Stability of Column Type Deep Mixing Ground on Inclined Foundation 227
Yuta Toshinari, Syusaku Matsuda, Masaki Kitazume, and Binh Nguyen

Construction and Verification Testing of Cement Deep Soil Mix Panels to Mitigate Seismic Displacements for the Evergreen Line Rapid Transit Project 237
Ali Azizian, Brian E. Hall, Juan I. Baez, Alan Moat, and Blair Squire

Construction of a Deep Cutoff Wall along the Mississippi River at East Alton, IL 249
Raffaella Granata, Jo Tucker, Matteo Bertoni, and Wesley Schmutzler

Cyclic Unconfined Compression Test of Cement-Treated Soils 259
Tsutomu Namikawa, Yoshio Suzuki, Sadatomo Onimaru, Takuya Tsukamoto, Ryo Kurosawa, and Kentaro Shimada

Design and Construction of a Soil Cement Mixed TBM Retrieval Shaft in Porous Limestone 269
Terrence Carroll, Chu Ho, Thomas Richards, and Jose Torres

Design and Construction of Column Supported Embankment Using Deep Soil Mixing Columns and Reinforced Concrete Load Transfer Slab 279
King H. Chin, Heidi P. Cashman, and Chris Barnes

Determining the Tensile Strength of Soil-Cement 289
Brian Wilson and Jim Coull

Dissecting a 107-Year-Old Dam with a Barrier Wall 299
Edwin R. Friend, Darren Brinker, Jeff Martin, Douglas Raitt, and Robert Huzjak

Ground Treatment by Combination of CSM and Jet-Grouting in Hong Kong 316
Alex Chan, Julien Landrot, Fabrice Mathieu, and Derek Yung

© ASCE

High-Strength Ground-Improvement Using Low Water–Cement Ratio Slurry **325**
Takao Kono, Shinji Tamaki, Masamichi Aoki, and Toshio Yonezawa

Innovation and Collaboration in Deep Mixing **336**
George Filz and Donald Bruce

Mass Stabilization of Organic Soils for Steel Tank Support at Port Everglades, Florida **354**
Joseph A. Mann and Allen L. Sehn

Mechanical Behavior of Soilcrete Mixtures: An Experimental Parametric Study **365**
O. Helson, J. Eslami, A.-L. Beaucour, A. Noumowe, and P. Gotteland

A New Parameter for the Evaluation of Mixing Quality in Deep Soil Mixing **375**
Diego Bellato, Ignazio P. Marzano, and Paolo Simonini

Panels Made by the Deep Mixing Method for a Building Pit Support in a Slope **385**
Roman Marte, Florian Scharinger, and Roland Lüftenegger

The Remediation of Buckeye Lake Dam, Ohio: Deep Mixing as an Interim Risk Reduction Measure and Key Component of Final Design **395**
Daniel P. Stare, George Filz, and Donald A. Bruce

Single Column Mixing—Double Rotary Head (SCM-DRH)—First Experiences with a New Soil Mixing Tool **405**
Franz-Werner Gerressen and Robert McGall

Soil Cement Columns (SCC) in Japan **415**
Yoshinori (Jimmy) Oshiro

Soil Mixing for Passive Seismic Protection System **424**
Giuseppe Panetta, Giuseppe Iorio, Ignazio Paolo Marzano, and Massimo Grisolia

Soil Mixing for the SR-83 Project in Florida **434**
Wesley Schmutzler, Gray Mullins, and Matteo Bertoni

Specialty Jet Grouting and Deep Mixing for DC Clean Rivers **445**
Joseph K. Cavey, Kenneth Ivanetich, and Joseph A. Mann

© ASCE

Use of Real-Time Monitoring Data to Interpret Variable Subsurface Conditions and Validate Construction for a Large Deep Mixing Scheme Using Cutter Soil Mixing to Support MSE Walls at Kitimat LNG, BC, Canada.....459
Marina S. W. Li, Brian W. Wilson, and Franz-Werner Gerressen

Using a Shallow Mixing Layer to Reinforce Deep Mixing Columns during Embankment Construction.....471
Binh Nguyen, Tomohide Takeyama, and Masaki Kitazume

Diaphram Walls

Diaphragm Wall Construction Performance Using Hydrocutter Technology at the Center Hill Dam Foundation Remediation Project 481
Michael Arnold, Bob Faulhaber, Joe Nichols, and Alex Cartwright

Diaphragm Walls for Deep Shafts for the Anchorage of a Suspension Bridge in Africa.....491
Joern M. Seitz

Evolution of USACE Seepage Cutoff Wall Contracts.....502
Georgette Hlepas and Vanessa Bateman

Forensic Investigation of a Slurry Wall Failure: A Case Study.....513
Behrooz Ghahreman Nejad, Trevor Osborne, and John P. Carter

The On-Site Management of Polymer Support Fluids for the Construction of Drilled Shafts and Diaphragm Walls 523
Stephan A. Jefferis, Yue Ouyang, Paul Wiltcher, Tony Suckling, and Carlos Lam

Remedial Cutoff Walls for Dams in the U.S.: 40 Years of Case Histories 533
Donald A. Bruce

The Role of Real-Time Monitoring in Controlling the Installation and Assessing the Performance of a Plastic Concrete Cut-Off.....548
William J. S. Sheehy, Donald A. Bruce, and Sui K. A. Lim

Structural Diaphragm Walls at the Red Rock Hydroelectric Project.....561
Rachael V. Bisnett, Thomas G. Andrews, Hani Habib, and Nicolas Willig-Friedrich

Three Dimensional Effect of Grouted Discontinuous Berms for Passive Support of Diaphragm Walls 571
Muhammad M. El-Sherbiny, Rami M. El-Sherbiny, and Hussein El-Mamlouk

© ASCE