

# Soils and Rock Instrumentation, Behavior, and Modeling



*Edited  
by*

Louis Ge, Ph.D., P.E.  
Boming Tang, Ph.D.  
WeiHong Wei, Ph.D.  
Renpeng Chen, Ph.D.

**ASCE**



GEOTECHNICAL SPECIAL PUBLICATION NO. 194

# SOILS AND ROCK INSTRUMENTATION, BEHAVIOR, AND MODELING

---

SELECTED PAPERS FROM THE 2009 GEOHUNAN INTERNATIONAL CONFERENCE

---

August 3–6, 2009  
Changsha, Hunan, China

HOSTED BY  
Changsha University of Science and Technology, China

CO-SPONSORED BY  
ASCE Geo-Institute, USA  
Asphalt Institute, USA  
Central South University, China  
Chinese Society of Pavement Engineering, Taiwan  
Chongqing Jiaotong University, China  
Deep Foundation Institute, USA  
Federal Highway Administration, USA  
Hunan University, China  
International Society for Asphalt Pavements, USA  
Jiangsu Transportation Research Institute, China  
Korea Institute of Construction Technology, Korea  
Korean Society of Road Engineers, Korea  
Texas Department of Transportation, USA  
Texas Transportation Institute, USA  
Transportation Research Board (TRB), USA

EDITED BY  
Louis Ge, Ph.D., P.E.  
Boming Tang, Ph.D.  
WeiHong Wei, Ph.D.  
Renpeng Chen, Ph.D.



Published by the American Society of Civil Engineers



Library of Congress Cataloging-in-Publication Data.

Soils and rock instrumentation, behavior, and modeling ; selected papers from the 2009 GeoHunan International Conference, August 3-6, 2009, Changsha, Hunan, China / hosted by Changsha University of Science and Technology, China ; co-sponsored by ASCE Geo-Institute, USA ; edited by Louis Ge.

p. cm. -- (Geotechnical special publication ; no. 194)

Includes bibliographical references and indexes.

ISBN 978-0-7844-1046-2

1. Road materials--Congresses. 2. Soils--Congresses. 3. Engineering geology--Instruments--Congresses. 4. Pavements--Congresses. I. Ge, Louis. II. Changsha li gong da xue. III. American Society of Civil Engineers. Geo-Institute. IV. GeoHunan International Conference on Challenges and Recent Advances in Pavement Technologies and Transportation Geotechnics (2009 : Changsha, Hunan Sheng, China)

TE200.S63 2009

624.1'51--dc22

2009022725

American Society of Civil Engineers  
1801 Alexander Bell Drive  
Reston, Virginia, 20191-4400

[www.pubs.asce.org](http://www.pubs.asce.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 therefore. This information should not be used without first securing competent advice with respect to its suitability for any general or specific application. Anyone utilizing this 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 reprints.*

You can obtain instant permission to photocopy ASCE publications by using ASCE's online permission service (<http://pubs.asce.org/permissions/requests/>). Requests for 100 copies or more should be submitted to the Reprints Department, Publications Division, ASCE, (address above); email: [permissions@asce.org](mailto:permissions@asce.org). A reprint order form can be found at <http://pubs.asce.org/support/reprints/>.

Copyright © 2009 by the American Society of Civil Engineers. All Rights Reserved.  
ISBN 978-0-7844-1046-2  
Manufactured in the United States of America.

## Geotechnical Special Publications

- 1 *Terzaghi Lectures*
- 2 *Geotechnical Aspects of Stiff and Hard Clays*
- 3 *Landslide Dams: Processes, Risk, and Mitigation*
- 7 *Timber Bulkheads*
- 9 *Foundations & Excavations in Decomposed Rock of the Piedmont Province*
- 11 *Dynamic Response of Pile Foundations - Experiment, Analysis and Observation*
- 14 *Geotechnical Aspects of Karst Terrains*
- 15 *Measured Performance Shallow Foundations*
- 16 *Special Topics in Foundations*
- 17 *Soil Properties Evaluation from Centrifugal Models*
- 18 *Geosynthetics for Soil Improvement*
- 19 *Mine Induced Subsidence: Effects on Engineered Structures*
- 21 *Hydraulic Fill Structures*
- 22 *Foundation Engineering*
- 23 *Predicted and Observed Axial Behavior of Piles*
- 24 *Resilient Moduli of Soils: Laboratory Conditions*
- 25 *Design and Performance of Earth Retaining Structures*
- 27 *Geotechnical Engineering Congress*
- 28 *Detection of and Construction at the Soil/Rock Interface*
- 29 *Recent Advances in Instrumentation, Data Acquisition and Testing in Soil Dynamics*
- 32 *Embankment of Dams - James L. Sherard Contributions*
- 33 *Excavation and Support for the Urban Infrastructure*
- 34 *Piles Under Dynamic Loads*
- 35 *Geotechnical Practice in Dam Rehabilitation*
- 37 *Advances in Site Characterization: Data Acquisition, Data Management and Data Interpretation*
- 39 *Unsaturated Soils*
- 40 *Vertical and Horizontal Deformations of Foundations and Embankments*
- 41 *Predicted and Measured Behavior of Five Spread Footings on Sand*
- 42 *Serviceability of Earth Retaining Structures*
- 43 *Fracture Mechanics Applied to Geotechnical Engineering*
- 44 *Ground Failures Under Seismic Conditions*
- 45 *In Situ Deep Soil Improvement*
- 46 *Geo-environment 2000*
- 47 *Geo-Environmental Issues Facing the Americas*
- 48 *Soil Suction Applications in Geotechnical Engineering*
- 49 *Soil Improvement for Earthquake Hazard Mitigation*
- 50 *Foundation Upgrading and Repair for Infrastructure Improvement*
- 51 *Performance of Deep Foundations Under Seismic Loading*
- 52 *Landslides Under Static and Dynamic Conditions - Analysis, Monitoring, and Mitigation*
- 53 *Landfill Closures - Environmental Protection and Land Recovery*
- 54 *Earthquake Design and Performance of Solid Waste Landfills*
- 55 *Earthquake-Induced Movements and Seismic Remediation of Existing Foundations and Abutments*
- 56 *Static and Dynamic Properties of Gravelly Soils*
- 57 *Verification of Geotechnical Grouting*
- 58 *Uncertainty in the Geologic Environment*
- 59 *Engineered Contaminated Soils and Interaction of Soil Geomembranes*
- 60 *Analysis and Design of Retaining Structures Against Earthquakes*
- 61 *Measuring and Modeling Time Dependent Soil Behavior*
- 62 *Case Histories of Geophysics Applied to Civil Engineering and Public Policy*
- 63 *Design with Residual Materials: Geotechnical and Construction Considerations*
- 64 *Observation and Modeling in Numerical Analysis and Model Tests in Dynamic Soil-Structure Interaction Problems*
- 65 *Dredging and Management of Dredged Material*
- 66 *Grouting: Compaction, Remediation and Testing*
- 67 *Spatial Analysis in Soil Dynamics and Earthquake Engineering*
- 68 *Unsaturated Soil Engineering Practice*
- 69 *Ground Improvement, Ground Reinforcement, Ground Treatment: Developments 1987-1997*
- 70 *Seismic Analysis and Design for Soil-Pile-Structure Interactions*
- 71 *In Situ Remediation of the Geo-environment*
- 72 *Degradation of Natural Building Stone*
- 73 *Innovative Design and Construction for Foundations and Substructures Subject to Freezing and Frost*

- 74 *Guidelines of Engineering Practice for Braced and Tied-Back Excavations*
- 75 *Geotechnical Earthquake Engineering and Soil Dynamics III*
- 76 *Geosynthetics in Foundation Reinforcement and Erosion Control Systems*
- 77 *Stability of Natural Slopes in the Coastal Plain*
- 78 *Filtration and Drainage in Geotechnical/Geoenvironmental Engineering*
- 79 *Recycled Materials in Geotechnical Applications*
- 80 *Grouts and Grouting: A Potpourri of Projects*
- 81 *Soil Improvement for Big Digs*
- 82 *Risk-Based Corrective Action and Brownfields Restorations*
- 83 *Design and Construction of Earth Retaining Systems*
- 84 *Effects of Construction on Structures*
- 85 *Application of Geotechnical Principles in Pavement Engineering*
- 86 *Big Digs Around the World*
- 87 *Jacked Tunnel Design and Construction*
- 88 *Analysis, Design, Construction, and Testing of Deep Foundations*
- 89 *Recent Advances in the Characterization of Transportation Geo-Materials*
- 90 *Geo-Engineering for Underground Facilities*
- 91 *Special Geotechnical Testing: Central Artery/Tunnel Project in Boston, Massachusetts*
- 94 *Performance Confirmation of Constructed Geotechnical Facilities*
- 95 *Soil-Cement and Other Construction Practices in Geotechnical Engineering*
- 96 *Numerical Methods in Geotechnical Engineering: Recent Developments*
- 97 *Innovations and Applications in Geotechnical Site Characterization*
- 98 *Pavement Subgrade, Unbound Materials, and Nondestructive Testing*
- 99 *Advances in Unsaturated Geotechnics*
- 100 *New Technological and Design Developments in Deep Foundations*
- 101 *Slope Stability 2000*
- 102 *Trends in Rock Mechanics*
- 103 *Advances in Transportation and Geoenvironmental Systems Using Geosynthetics*
- 104 *Advances in Grouting and Ground Modification*
- 105 *Environmental Geotechnics*
- 106 *Geotechnical Measurements: Lab & Field*
- 107 *Soil Dynamics and Liquefaction 2000*
- 108 *Use of Geophysical Methods in Construction*
- 109 *Educational Issues in Geotechnical Engineering*
- 110 *Computer Simulation of Earthquake Effects*
- 111 *Judgment and Innovation: The Heritage and Future of the Geotechnical Engineering Profession*
- 112 *Soft Ground Technology*
- 113 *Foundations and Ground Improvement*
- 114 *Soils Magic*
- 115 *Expansive Clay Soils and Vegetative Influence on Shallow Foundations*
- 116 *Deep Foundations 2002: An International Perspective on Theory, Design, Construction, and Performance*
- 117 *Discrete Element Methods: Numerical Modeling of Discontinua*
- 118 *A History of Progress: Selected U.S. Papers in Geotechnical Engineering*
- 119 *Soil Behavior and Soft Ground Construction*
- 120 *Grouting and Ground Treatment*
- 121 *Probabilistic Site Characterization at the National Geotechnical Experimentation Sites*
- 122 *Sinkholes and the Engineering and Environmental Impacts of Karst*
- 123 *Recent Advances in Materials Characterization and Modeling of Pavement Systems*
- 124 *GeoSupport 2004: Drilled Shafts, Micropiling, Deep Mixing, Remedial and Specialty Foundation Systems*
- 125 *Current Practices and Future Trends in Deep Foundations*
- 126 *Geotechnical Engineering for Transportation Projects*
- 127 *Recycled Materials in Geotechnics*
- 128 *Soil Constitutive Models: Evaluation, Selection, and Calibration*
- 129 *Advances in Designing and Testing Deep Foundations*
- 130 *Advances in Pavement Engineering*
- 131 *Contemporary Issues in Foundation Engineering*
- 132 *Advances in Deep Foundations: In Memory of Michael W. O'Neill*
- 133 *Earthquake Engineering and Soil Dynamics*
- 134 *Soil Dynamics Symposium in Honor of Professor Richard D. Woods*
- 135 *Erosion of Soils and Scour of Foundations*

- 136 *Innovations in Grouting and Soil Improvement*
- 137 *Legal and Liability Issues in Geotechnical Engineering*
- 138 *Site Characterization and Modeling*
- 139 *Calibration of Constitutive Models*
- 140 *Slopes and Retaining Structures under Seismic and Static Conditions*
- 141 *International Perspectives on Soil Reinforcement Applications*
- 142 *Waste Containment and Remediation*
- 143 *Geomechanics: Testing, Modeling, and Simulation*
- 144 *Sinkholes and the Engineering and Environmental Impacts of Karst*
- 145 *Seismic Performance and Simulation of Pile Foundations in Liquefied and Laterally Spreading Ground*
- 146 *Asphalt Concrete: Simulation, Modeling and Experimental Characterization*
- 147 *Unsaturated Soils 2006*
- 148 *Advances in Unsaturated Soil, Seepage, and Environmental Geotechnics*
- 149 *Site and Geomaterial Characterization*
- 150 *Soil and Rock Behavior and Modeling*
- 151 *Advances in Earth Structures: Research to Practice*
- 152 *Ground Modification and Seismic Mitigation*
- 153 *Foundation Analysis and Design: Innovative Methods*
- 154 *Pavement Mechanics and Performance*
- 155 *Underground Construction and Ground Movement*
- 156 *Geomechanics II: Testing, Modeling, and Simulation*
- 157 *Computer Applications in Geotechnical Engineering*
- 158 *Contemporary Issues in Deep Foundations*
- 159 *Case Studies in Earth Retaining Structures*
- 160 *Dynamic Response and Soil Properties*
- 161 *Embankments, Dams, and Slopes: Lessons from the New Orleans Levee Failures and Other Issues*
- 162 *Problematic Soils and Rocks and In Situ Characterization*
- 163 *Geoenvironmental Engineering*
- 164 *Innovative Applications of Geophysics in Civil Engineering*
- 165 *Geosynthetics in Reinforcement and Hydraulic Applications*
- 166 *Educational Activities in Geotechnical Engineering*
- 167 *Geotechnics of Soil Erosion*
- 168 *Grouting for Ground Improvement: Innovative Concepts and Applications*
- 169 *Soil and Material Inputs for Mechanistic-Empirical Pavement Design*
- 170 *Probabilistic Applications in Geotechnical Engineering*
- 171 *Advances in Shallow Foundations*
- 172 *Soil Improvement*
- 173 *Advances in Measurement and Modeling of Soil Behavior*
- 174 *Designing Our Underground Space*
- 175 *Field Measurements in Geomechanics 2007*
- 176 *Analysis of Asphalt Pavement Materials and Systems: Emerging Methods*
- 177 *GeoCongress 2008: Geotechnics of Waste Management and Remediation*
- 178 *GeoCongress 2008: Geosustainability and Geohazard Mitigation*
- 179 *GeoCongress 2008: Characterization, Monitoring, and Modeling of GeoSystems*
- 180 *From Research to Practice in Geotechnical Engineering*
- 181 *Geotechnical Earthquake Engineering and Soil Dynamics IV*
- 182 *Pavements and Materials: Characterization, Modeling, and Simulation*
- 183 *Sinkholes and the Engineering and Environmental Impacts of Karst*
- 184 *Pavements and Materials: Modeling, Testing, and Performance*
- 185 *Contemporary Topics in Deep Foundations*
- 186 *Contemporary Topics in In-Situ Testing, Analysis, and Reliability of Foundations*
- 187 *Contemporary Topics in Ground Modification, Problem Soils, and Geo-Support*
- 188 *Advances in Ground Improvement: Research to Practice in USA and China*
- 189 *Characterization, Modeling, and Performance of Geomaterials*
- 190 *Asphalt Material Characterization, Accelerated Testing, and Highway Management*
- 191 *Road Pavement Material Characterization and Rehabilitation*
- 192 *Recent Advancement in Soil Behavior, In Situ Test Methods, Pile Foundations, and Tunneling*
- 193 *Material, Design, Construction, Maintenance, and Testing of Pavement*

*This page intentionally left blank*

---

# Preface

The papers in this Geotechnical Special Publication were presented in the session of Soils and Rock Instrumentation, Behavior and Modeling at GeoHunan International Conference: Challenges and Recent Advances in Pavement Technologies and Transportation Geotechnics. The conference was hosted by Changsha University of Science and Technology on August 3-6, 2009.



*This page intentionally left blank*

---

# Contents

<b>Grout Efficiency of Lifting Structure in Soft Clay .....</b>	<b>1</b>
James -C. Ni and Wen-Chieh Cheng	
<b>Modeling Resilient Modulus of Unbound Granular Materials under Repeated Loading .....</b>	<b>9</b>
Cheng Chen, Louis Ge, and Jia Sheng Zhang	
<b>Study on the Deformation and Evolution Mechanism of Soil-Rock-Mixture Slope under Excavation Disturbance .....</b>	<b>16</b>
Zhong Zhou, Ru-Song Nie, Bao-Chen Liu, and Xiao-Li Yang	
<b>Development and Application of Constitutive Model for Simulation of Mechanical Behavior of Granular Material.....</b>	<b>24</b>
Xueyan Liu, A. Scarpas, C. Kasbergen, and W. X. Zhang	
<b>Application of Fuzzy Sets to Geological Strength Index (GSI) System Used in Rock Slope .....</b>	<b>30</b>
Yong-Jie Zhang, Wen-Gui Cao, and Ming-Hua Zhao	
<b>Measurement of Soil Air Suction Change during Freezing-Thawing Process.....</b>	<b>36</b>
Yan Liu, Xinbao Yu, and Xiong (Bill) Yu	
<b>Investigation of the Performance of Flexible Airport Pavements under Moving Aircraft Wheel Loads with Wander Using Finite Element Analysis.....</b>	<b>44</b>
Dona Johnson and Beena Sukumaran	
<b>Characteristics of Pore Pressure and Volume Change during Undrained Loading of Unsaturated Compacted Granite Soil.....</b>	<b>50</b>
Chan-Kee Kim, Woong-Ki Hwang, Yongkyu Choi, Minhee Lee, and Tae-Hyung Kim	
<b>Sonic Wave Testing Technique in Lamellar Rock Mass.....</b>	<b>57</b>
Qingfa Chen, Keping Zhou, and Feng Gao	
<b>The Pumping Test Data Analyses of Andesite Rock Blocks Aquifer with Varied Hydraulic Boundaries by Generalized Radial Flow Model.....</b>	<b>64</b>
Wen-Chieh Cheng and James -C. Ni	
<b>Constitutive Model of Soil-Structure Interface under Constant Stress Increment Ratio Stress Paths .....</b>	<b>72</b>
Ai-Zhao Zhou, Ting-Hao Lu, and Zhuang-Ping Gao	
<b>A Dynamic Damage Statistical Constitutive Model of Rock Considering Strain Rate under Uniaxial Loading Conditions.....</b>	<b>78</b>
Heng Zhao, Wen-Gui Cao, and Ling Zhang	
<b>The Application of PFWD in Sub-Grade Compactness Test.....</b>	<b>84</b>
Peng Wang and Chengchao Gua	
<b>Research on the Disturbed State Concept for Soft Clay Roadbed.....</b>	<b>92</b>
Xiao-Jun Yu and Jian-Yong Shi	