

State of the Art and Practice in Earthquake Induced Soil Liquefaction Assessment

Committee

Edward Kavazanjian, Jr.

Chair

EDWARD KAVAZANJIAN, JR. (NAE) is the Ira A. Fulton Professor of Geotechnical Engineering in the School of Sustainable Engineering and the Built Environment at Arizona State University in Tempe. He joined the faculty at Arizona State University in August 2004 after 20 years as a practicing geotechnical engineer. Dr. Kavazanjian's expertise includes geotechnical engineering for infrastructure development with a focus on seismic design. He is particularly well-known for his work on seismic design of transportation facilities and waste containment systems and has delivered keynote addresses and state-of-the-art papers on these topics at international conferences. Dr. Kavazanjian is the lead author of the US Federal Highway Administration guidance document on LRFD Seismic Design for Geotechnical Transportation Features and Structural Foundations. He has served as principal or co-principal investigator on National Science Foundation and California Integrated Waste Management Board research projects on seismic hazard mitigation and waste containment system design and performance and he is also co-author of the U.S. Environmental Protection Agency's guidance document on seismic design for municipal solid waste landfill facilities. Dr. Kavazanjian is a registered professional engineer in Arizona, California, and Washington, and a Diplomat of the Academy of Geo Professionals. He holds B.S. and M.S. degrees in civil engineering from Massachusetts Institute of Technology, and a Ph.D. in geotechnical engineering from the University of California at Berkeley.

Jose E. Andrade

Member

JOSÉ E. ANDRADE is a Professor in the Division of Engineering and Applied Science at Caltech after serving four years at Northwestern University as an assistant professor in Theoretical and Applied Mechanics. His research interests lie in the area of computational mechanics with application to problems at the interface of physics and mechanics to develop predictive analytical and numerical models for granular/porous materials (e.g., soils, rocks, foam, bone, etc.). In the area of earthquake-induced liquefaction, Dr. Andrade has proposed predictive models based on physical principles as an alternative to empirical methods. Dr. Andrade serves on the editorial board of four leading international journals in the field: Acta Geotechnica, Journal for Numerical and Analytical Methods in Geomechanics, Computers & Geotechnics, and Computational Particle Mechanics. Dr. Andrade is the recipient of several honors and awards including the 2006 Zienkiewicz Medal in computational mechanics, the 2010 NSF CAREER Award, the 2010 Young Investigator Award from the U.S. AFOSR, the 2011 Arthur Casagrande Career Development Award from ASCE, and the 2011 Rocafuerte Medal for Scientific and Technological Advancements from the Republic of Ecuador. His work is currently funded by NSF, DTRA, NASA, and AFOSR. Dr. Andrade received his B.S. degree from Florida Institute of Technology and his M.S. and Ph.D. degrees in geomechanics from Stanford University.

Kandiah Arulmoli

Member

KANDIAH "ARUL" ARULMOLI is the president and principal of Earth Mechanics, Inc., a geotechnical and earthquake engineering consulting firm specializing in transportation infrastructure. He has more than 30 years of experience in soil-structure interaction, seismic site response evaluation, and field and laboratory testing. He has a broad-based technical background in geotechnical engineering, and is a recognized expert in the area of geotechnical earthquake engineering. Since 1978, he has contributed to the improvement of design of California's infrastructure to withstand earthquakes through better understanding of the behavior of the geotechnical materials upon which the structures are founded. Dr. Arulmoli was a member of the California Seismic Safety Commission from 2005-2009 and 2010-2011. While serving on the Commission, he chaired the committee that reviewed the Pacific Earthquake Engineering Center's activities and served on other Commission committees and activities to help improve the seismic safety of Californians. He was a member of the American Society of Civil Engineers' Coasts, Oceans, Ports, and Rivers Institute team that visited Chile in April 2010 to access and learn from the effects of the February 27, 2010 magnitude 8.8 Chile earthquake. Dr. Arulmoli was responsible for evaluating performance of two sites at the Port of Los Angeles that suffered damage during the January 1994 Northridge earthquake. The evaluation included various types of geotechnical analysis, ranging from simplified liquefaction analysis to finite-element computer modeling, to verify the past analysis procedures used in design of the wharf structures and to improve them for future projects. Dr. Arulmoli earned his B.S. degree in civil engineering from the University of Sri Lanka and his M.S. and Ph.D. degrees in civil engineering with emphasis in geotechnical engineering from the University of California at Davis. He is a licensed civil and geotechnical engineer in California.

Brian F. Atwater

Member

BRIAN ATWATER (NAS) is a U.S. Geological Survey geologist affiliated with the University of Washington. His earthquake-related research began in 1983 with using alluvial-fan deposits to estimate recurrence intervals for coseismic growth of an anticline near Coalinga, California. Since 1985 he has focused on earthquake and tsunami hazards at subduction zones. At the Cascadia Subduction Zone he studied geologic evidence of land-level change, tsunamis, and liquefaction. These studies branched into geologic calibrations in Alaska and Chile; comparisons with written records of an Edo-period tsunami in Japan; paleotsunami research in Indonesia and Thailand; and collaborations with scientists from Pakistan. The international umbrellas included fellowships in Japan, USAID projects on Indian Ocean shores, UNESCO projects on the Makran Subduction Zone, and a Fulbright Fellowship in Indonesia. In a Japanese demonstration project that focused on paleoliquefaction, Dr. Atwater used giant sediment slices to learn that subsurface dikes and sills are common beneath Columbia River banks where liquefaction failed to produce surficial evidence during the 1700 Cascadia earthquake. His current work extends to earthquake-hazard assessment in the Caribbean and service on a California advisory board on water resources and ecosystem restoration. Dr. Atwater holds B.S. and M.S. degrees in geology from Stanford University (1974) and a Ph.D. in geology from the University of Delaware (1980).

John T. Christian

Member

JOHN T. CHRISTIAN (NAE) retired from Stone & Webster Engineering Corporation as a Vice President and is now a consulting engineer in Burlington, Massachusetts. His primary area of interest is geotechnical engineering. Much of his early work involved developing and applying numerical methods such as the finite element method. He has also worked on reliability methods for geotechnical applications, soil dynamics, and earthquake engineering on a broad range of civil engineering projects. Dr. Christian's current interests are largely focused on the use of reliability techniques in geotechnical engineering and on earthquake engineering. Much of his work in industry was associated with power generating facilities including, but not limited to, nuclear power plants. Dr. Christian is also interested in the evolving procedures and standards for undergraduate education, especially as reflected in the accreditation process. He received his B.S., M.S., and Ph.D. degrees in civil engineering from the Massachusetts Institute of Technology.

Russell Green

Member

RUSSELL GREEN is a Professor of Civil and Environmental Engineering (geotechnical) at Virginia Polytechnic Institute and State University in Blacksburg, Virginia. Russell's research focuses on engineering seismology, geotechnical earthquake engineering, and soil improvement with particular emphasis on modern liquefaction evaluations, liquefaction risk mitigation, paleoliquefaction investigations, and post-earthquake investigations. Prior to joining the faculty at Virginia Tech in August 2008, Russell was on the faculty of the University of Michigan for 7 years, served as a member of the technical staff (earthquake engineer) for the U.S. Defense Nuclear Facilities Safety Board for 6 years, and served on active duty in the U.S. Marine Corps for 4 years (honorably discharged at the rank of Sergeant). Russell is a registered professional engineer in the Commonwealth of Virginia. He received his bachelor's degree in civil engineering from Rensselaer Polytechnic Institute, his master's degree in civil engineering (structures) from the University of Illinois at Urbana-Champaign, and his doctoral degree in civil engineering (geotechnical) from Virginia Polytechnic Institute and State University.

Steven L. Kramer

Member

STEVEN L. KRAMER joined the geotechnical group in the University of Washington's Department of Civil Engineering in 1984. His primary research interests include soil liquefaction, site response analysis, seismic slope stability, and hazard analysis. Much of his current research work is in the area of performance-based earthquake engineering, specifically, the integration of probabilistic response analyses with probabilistic seismic hazard analyses. Kramer has been the recipient of the Presidential Young Investigator Award from the National Science Foundation, the Arthur Casagrande Professional Development Award from ASCE, the Walter Huber Research Prize from ASCE, the ASCE Norman Medal, and he was named the 2012 Academic Engineer of the Year by the Puget Sound Engineering Council. He is the author of the book Geotechnical Earthquake Engineering and co-developer of the computer programs, ProShake and EduShake. He was a senior research scientist in the International Centre for Geohazards at the Norwegian Geotechnical Institute (NGI) in 2003 and is also a member of the faculty of the European School for Advanced Studies in the Reduction of Seismic Risk (the ROSE School) at the University of Pavia in Italy. Kramer has served as a consultant to private firms and government agencies on earthquake-related projects in the U.S. and abroad. Dr. Kramer received his B.S., M.Eng., and Ph.D. degrees from the University of California at Berkeley in 1977, 1979, and 1985, respectively.

Lelio Mejia

Member

LELIO MEJIA is a principal engineer and vice president of URS. Dr. Mejia has been involved with a broad range of geotechnical, earthquake, dam, and foundation engineering projects. He has extensive experience in soil liquefaction and the use of ground treatment methods to mitigate the effects of liquefaction. He has also conducted soil-structure interaction analyses of hydraulic structures and power plant and harbor facilities, performed seismic risk analyses, and developed designs for earthquake ground motions for dams, industrial facilities, bridges, and high-rise buildings. He has conducted research on the use of three-dimensional finite element techniques and fully nonlinear models for the dynamic response analysis of dams and earth structure and on the mechanisms of liquefaction failure during earthquakes. He is a Secretarial Appointee to the Advisory Committee on Structural Safety of the Department of Veterans Affairs Facilities and is currently vice-chair of the Governance Board of the National Network for Earthquake Engineering Simulation (NEES). He has served as a National Science Foundation (NSF) Panelist for the CAREER Program and other NSF research programs in Geotechnical and Geohazards Systems and has served on technical review boards for the U.S. Bureau of Reclamation, the U.S. Army Corps of Engineers, and the California Department of Water Resources on various dam projects and for other owners on various engineering projects. Dr. Mejia earned his B.S. in civil engineering from the Universidad Javeriana, in Bogota, Colombia and his M.S. and Ph.D. degrees in geotechnical engineering from the University of California at Berkeley.

James K. Mitchell

Member

JAMES K. MITCHELL (NAS/NAE) is currently University Distinguished Professor Emeritus at Virginia Polytechnic Institute and State University and consulting geotechnical engineer. Prior to joining Virginia Tech in 1994, he served on the faculty at the University of California at Berkeley, where he held the Edward G. Cahill and John R. Cahill Chair in the Department of Civil and Environmental Engineering until the time of his retirement in 1993. Concurrent to his tenure at UC Berkeley, he was chairman of civil engineering from 1979-84 and research engineer in the Institute of Transportation Studies and in the Earthquake Engineering Research Center. His primary research and consulting activities have focused on experimental and analytical studies of soil behavior related to geotechnical problems, admixture stabilization of soils, soil improvement and ground reinforcement, physicochemical phenomena in soils, environmental geotechnics, time-dependent behavior of soils, in-situ measurement of soil properties, and mitigation of ground failure risk during earthquakes. He has authored more than 375 publications, including the graduate level text and geotechnical reference, *Fundamentals of Soil Behavior*. A licensed civil engineer and geotechnical engineer in California and professional engineer in Virginia, Dr. Mitchell has served as chairman or officer for numerous national and international organizations, including chairman of the U.S. National Committee for the International Society for Soil Mechanics and Foundation Engineering and vice president of the International Society for Soil Mechanics and Geotechnical Engineering. He chaired the National Research Council's (NRC) Geotechnical Board as well as three NRC study committees and served as a member of several other NRC study committees. He has received numerous awards including the Norman Medal, the Walter L. Huber Research Prize, the Terzaghi Lecture Award and the Outstanding Projects and Leaders Award from the American Society of Civil Engineers, and the NASA Medal for Exceptional Scientific Achievement. He was elected to the National Academy of Engineering in 1976 and to the National Academy of Sciences in 1998. Dr. Mitchell received a Bachelor of Civil Engineering degree from Rensselaer Polytechnic Institute and M.S. and Sc.D. degrees in civil engineering from the Massachusetts Institute of Technology.

Ellen Rathje

Member

ELLEN RATHJE is the Warren S. Bellows Centennial Professor of Civil Engineering at the University of Texas at Austin. Her research encompasses the seismic stability of earth slopes, site response modeling, liquefaction evaluation and soil improvement, and the application of remote sensing to geotechnical phenomena. Dr. Rathje was one of the developers of a new in situ dynamic liquefaction test, which utilizes a large, truck-mounted hydraulic shaker to induce liquefaction in localized zones of saturated soil. This testing technique is the first of its kind and is expanding the tools available to study liquefaction in situ. Dr. Rathje has also been involved in centrifuge testing to evaluate soil improvement techniques such as prefabricated vertical drains. This research involved centrifuge testing of untreated and drain-treated slopes as well as numerical modeling of the centrifuge tests. Her current research efforts involve the use of remote sensing to measure deformations associated with liquefaction and lateral spreading. Dr. Rathje has also been involved in earthquake reconnaissance efforts through her participation as co-chair of the Geotechnical Extreme Events Reconnaissance (GEER) Association. She has participated and/or led several reconnaissance missions (1999 Kocaeli earthquake in Turkey, 2001 Bhuj earthquake in India, 2004 Niigata-ken Chuetsu earthquake in Japan, and the 2010 Haiti earthquake) and through this work has documented the occurrence of liquefaction during earthquakes. Dr. Rathje was a member of the Board of Directors of the Earthquake Engineering Research Institute (EERI) from 2010-2013 and a member of the Scientific Earthquake Studies Advisory Committee of the U.S. Geological Survey from 2007-2013. She received the Huber Research Prize from the American Society of Civil Engineers (ASCE) in 2010, the Hogentogler Award for outstanding paper from ASTM Committee D18 in 2010 (for a paper on in situ liquefaction testing), the Shamsheer Prakash Research Award in 2007, and the Shah Innovation Prize from EERI in 2006.

James R. Rice

Member

JAMES R. RICE (NAS and NAE) is the Mallinckrodt Professor of Engineering Sciences and Geophysics at Harvard University, in its School of Engineering and Applied Sciences and Department of Earth and Planetary Sciences. From 1965 to 1981, Rice was a professor at the Division of Engineering, Brown University. He holds B.S., M.S., and Ph.D. degrees in mechanics from Lehigh University. Rice studies phenomena relating to stressing, deformation, flow and fracture. That has been directed in recent years to geophysics (seismology, glaciology, tectonophysics), and to civil and environmental engineering hydrology and geomechanics. His seismic studies focus on the nucleation of earthquake rupture, thermo- and hydro-mechanical weakening of fault zones during seismic slip, fracture propagation through branched and offset fault systems, tsunami generation and propagation, and relations among stressing, seismicity, and deformation in or near continental and subduction fault systems, including the physics of aseismic deformation transients. His research related to hydrologic processes, including poroelastic-plastic effects and other fluid interactions in the deformation and failure of earth materials, has application to glacial flows, including rapid and episodic ice motions, glacial earthquakes, and massive ice-sheet under-flooding events as natural hydraulic fractures, and also to submarine and subaerial landslide processes.

Yumei Wang

Member

YUMEI WANG is a geohazards engineer at Oregon Department of Geology and Mineral Industries and focuses on building resilience to future earthquakes, tsunamis, and landslides. She has been an advisor to the National Research Council on landslide hazards and earthquake resilience, to the National Earthquake Hazards Reduction Program (NEHRP), and has taken part in post-earthquake assessments including the 2011 Tohoku Japan and 2010 Maule Chile disasters. Ms. Wang has performed liquefaction and lateral spreading analyses that include subsurface exploration and paleoseismic investigations, has developed liquefaction hazard maps, and is exploring liquefaction research needs to understand critical infrastructure risk in Oregon. Ms. Wang has been a guest on the PBS NewsHour, been interviewed by The New York Times, and appeared in documentaries produced by NOVA and National Geographic. Ms. Wang served as Congressional Fellow, sponsored by the American Association for the Advancement of Science (AAAS) in the U.S. Senate in Washington D.C., worked as a geotechnical consultant in California, and has a B.A. in geological sciences from the University of California at Santa Barbara and a M.S. in civil engineering from the University of California at Berkeley.