

Loren J. Lorig

Principal Geotechnical Engineer

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| <i>Expertise</i> | Geotechnical Engineering, Slope Stability, Numerical Modeling |
| <i>Education</i> | Ph.D. (Civil Engineering), 1984 University of Minnesota, Minneapolis, Minnesota, USA M.S.C.E. (Civil Engineering), 1975 University of Illinois, Urbana, Illinois, USA B.S.C.E. (Civil Engineering), 1973 Valparaiso University, Valparaiso, Indiana, USA |
| <i>Registration</i> | Registered Professional Engineer: Illinois, Maryland, Minnesota, and Pennsylvania |
| <i>Professional Affiliations</i> | Member: Tau Beta Pi, ISRM, ARMA, SME |
| <i>Honors</i> | <i>Journal of the Southern African Institute of Mining and Metallurgy</i> , Silver Medal Award (2020) ARMA, Outstanding Contributions to Rock Mechanics Award (2017) Society for Mining, Metallurgy & Exploration Inc. (SME), Rock Mechanics Award (2016) Indian Society for Rock Mechanics and Tunnelling Technology (1996), Best Paper, Underground Space Technology Golder Associates Prize (1984), Best Paper, ISRM Symposium on Design and Performance of Underground Excavations Consulting Engineers Council Scholarship National Award (1973) |
| <i>Keynote Lectures</i> | <i>XI Chilean Congress of Geotechnics, Tacna, Chile 2021</i> <i>Slope Stability Conferences: Santiago, Chile 2009; Vancouver, Canada, 2011; Cape Town, South Africa, 2015</i> <i>Discrete Fracture Network Eng. Conf., Vancouver, Canada, 2014</i> <i>7th Intl. Symp. On Ground Support, Perth, Australia, 2013</i> <i>ARMA, San Francisco, 2011</i> <i>Barrick Geomechanics and Hydrogeology Conference: Elko, Nevada, 2008; Kalgoorlie, Australia, 2011</i> <i>Int. FLAC/DEM Symposium: Minneapolis, Minnesota, 2008; Melbourne, Australia, 2011</i> <i>Jornada Técnica: Cálculo de Túneles, Madrid, Spain, 2009</i> <i>ISRM World Congress, Lisbon, Portugal, 2007</i> |

Professional Experience

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| 2017 – Present | <i>Itasca Consulting Group, Inc., Minneapolis, Minnesota Principal Geotechnical Engineer</i> |
| 2008 – 2016 | <i>Itasca International, Inc., Minneapolis, Minnesota Chief Executive Officer</i> |
| 1993 – 2008 | <i>Itasca S.A., Santiago, Chile Technical/General Manager and Principal Mining Engineer</i> |
| 1985 – 1993 | <i>Itasca Consulting Group, Inc., Minneapolis, Minnesota Senior Project Engineer</i> |
| 1984 – 1985 | <i>CSIRO Division of Geomechanics, Melbourne, Australia Senior Research Scientist</i> |
| 1983 – 1984 | <i>Charles Nelson and Associates, Minneapolis, Minnesota Design Engineer</i> |
| 1982 – 1983 | <i>Howard, Needles, Tammen and Bergendoff, Minneapolis, Minnesota Tunnel Engineer</i> |
| 1980 – 1982 | <i>University of Minnesota, Department of Civil and Mineral Engineering, Minneapolis, Minnesota Research Fellow</i> |
| 1976 – 1980 | <i>A. A. Mathews, Inc., Rockville, Maryland Assistant Vice President</i> |
| 1973 – 1976 | <i>University of Illinois, Department of Civil Engineering, Chicago, Illinois Research Assistant</i> |

Project Experience

Rock Mechanics Applied to Surface Mining: Consulting, field, and numerical modeling projects for diverse problems at some of the largest open-pit mines in the world, including Chuquicamata, Collahuasi and Escondida (Chile), Jwaneng and Orapa (Botswana), Superpit (Australia), Morenci and Bingham Canyon (USA), and Toquepala and Cuajone (Peru). Surface-mining activities: estimating rock mass properties, calibrating numerical models for slope-stability assessments, back-analyzing slope failures, and specifying remedial measures (dewatering, buttresses, step-outs, etc.). Static and dynamic analysis of tailings dams and dikes in highly active seismic areas, including assessment of stability and liquefaction potential of saturated sands and interpretation of laboratory test results to estimate soil properties. (Representative projects include Torito dam, Ovejeria dam, Quillayes dam, and retaining dikes at Escondida Mine, all in Chile.) Numerous subsidence analyses (both mining- and dewatering-induced) for surface and underground mines. Member of Geotechnical Review Boards for Las Bambas and Antapaccay (Peru), Cerro Colorado, Collahuasi and Antofagasta Mineral Mines (Chile), and all surface mines for Vale and Freeport McMoran, Inc. Itasca Project Manager for a large open-pit project, an international research and technology transfer project on the stability of rock slopes in open-pit mines. Co-author of Slope Design Methods (chapter 10) of *Guidelines for Open Pit Slope Design* (2009), Numerical Modelling (chapter 4) of *Guidelines for Evaluating Water in Pit Slope Stability* (2013), and Slope Design Considerations (chapter 5) of *Guidelines for Open Pit Slope Design in Weak Rocks* (2018). Lead author of Numerical Analysis (chapter 10) of *Rock Slopes — Civil and Mining Engineering* (2004) and Numerical Analysis (chapter 12) of *Rock Slope Engineering: Civil Applications*, Fifth Edition (2017).

Rock Mechanics Applied to Cave Mining: Consulting and numerical modeling projects for diverse problems in cave mining, including management of Itasca's involvement in the first phase of the International Caving Study, a worldwide study aimed at improving the understanding and performance of caving. Calibration of regional stress fields, extraction-level layout assessments, evaluation of caving potential and fragmentation, evaluation of ground-support methods and panel sequencing, and prediction of gravity flow of broken ore. Consulting services for Argyle Mine and Northparkes Mine (Australia), Henderson Mine (United States), Premier Mine, Finsch Mine and Koffiefontein Mine (South Africa), and Andina, Chuquicamata and El Teniente Mines (Chile). Member of Geotechnical Advisory Board for Far Southeast Mine (Philippines).

Geomechanics Applied to Civil Engineering: Consulting and numerical modeling for diverse problems in civil engineering. Collection and assimilation of geomechanical data, development of numerical models to represent problems, and analysis/interpretation of results. Representative activities include analysis of rockfill dam settlement (Bennett Dam, Canada), slope-stability analysis at Paiton power project (Indonesia) and Revelstoke Reservoir (Canada), analysis of stacked tunnels for Rio Piedras metro station (Puerto Rico), analysis of large detector-hall caverns for physics research, analysis of multiple parallel caverns at shallow depths (Finland), and analysis of an underground powerhouse complex for the Sogamoso hydroelectric project (Colombia). Extensive research in the engineering properties and numerical representation of shotcrete (reinforced and unreinforced), rock bolts, cable bolts, and soil nails. Member of the Board of Consultants for Clearwater Dam (USA), Board of Experts for hydroelectric projects (Ecuador), and Neutrino Cavern Advisory Board (USA).

Numerical Modeling in Geomechanics: Presentation of over 50 courses in more than 15 countries on numerical modeling methods, focusing on the application of numerical models to practical problems in mining and civil engineering. Instructor for graduate-level university courses in the United States, Sweden, Finland, and Chile. Author and co-author of more than 80 technical articles.