Branko Damjanac

ITASCA Consulting Group, Inc.
An Itasca International Company

Principal Engineer

Expertise	Rock Mechanics, Hydro-Mechanical Coupling, Hydraulic Fracturing, Dynamics in Geotechnical Engineering, Tool-Rock Interaction
Education	Ph.D. (Civil Engineering), 1996 M.S.C.E. (Civil Engineering), 1992 University of Minnesota, Minneapolis, Minnesota, United States B.S.C.E. (Civil Engineering), 1984 Belgrade University, Belgrade, Serbia
Professional Affiliations	Member: ARMA (American Rock Mechanics Association)
Honors	*Computers and Geotechnics*, 2019 Sloan Outstanding Paper Award
Keynote Lectures	*Recent Advances in Numerical Simulation of Hydraulic Fracture 1024, Rzezsov, Poland*

Professional Experience

	Itasca Consulting Group, Inc., Minneapolis, Minnesota
2000 – Present	*Principal Engineer*
1996 – Present	*Geotechnical Engineer*
1991– 1996	*University of Minnesota, Department of Civil Engineering* *Research Assistant/Post-Doctoral Associate*
1991 – 1993	*Itasca Consulting Group, Inc., Minneapolis, Minnesota* *Staff Engineer*
1984 – 1991	*Energoprojekt Consulting Company, Belgrade, Yugoslavia* *Consulting Engineer*

Project Experience

Design and Analysis of Geological Radioactive Waste Disposal: From 1991 until 2008, involved in different aspects of the U.S. program for geological disposal of high-level radioactive waste at Yucca Mountain, Nevada. Starting in 2001, manager of Itasca's long-term project with Bechtel-SAIC Company, U.S. Department of Energy (DOE) contactor for Yucca Mountain Project. Among other issues, the project involved: (a) stability analyses of the emplacement drifts and non-emplacement excavations at the Yucca Mountain site for different loading conditions, including in-situ stresses, thermally induced stresses, seismic ground shaking, and time-dependent strength degradation; and (b) investigations of the mechanics of dike propagation and the interaction between the dike and the emplacement drifts in case of volcanic intrusion into the repository. Previous work on the Yucca Mountain Project involves: (a) investigation of effect of thermo-mechanical-hydrological coupling on conditions of water percolation in an unsaturated rock mass around the emplacement drifts and the potential for water seepage into the drifts; (b) simulation of the Heated Drift Test (a large scale experiment involving heating a 50-m long tunnel) and analysis of the effects of large-scale heating on deformation of a rock mass and changes in rock-mass permeability; and (c) investigations of the influence of local seismicity, due to slip on the faults in vicinity of the repository, on variation of groundwater levels at the proposed Yucca Mountain site.

Investigated the effects of incidental borehole intrusion into Waste Isolation Pilot Plant (WIPP), New Mexico, including analysis and modeling of the expulsion of granular material due to gas migration caused by intrusion of the borehole into the waste repository; analysis of coupled, fluid flow-deformation; analysis of the conditions for erosion of the granular material, in which erosion as a manifestation of local (sanding) and global (plastic flow) instability was considered, as well as transition conditions between two modes of instability.

Investigated the long-term stability of the emplacement caverns and the shafts for the proposed low- and intermediate-level nuclear waste repository at the Bruce site, Ontario, Canada. The work was done for the Nuclear Waste Management Organization (NWMO) of Canada. Stability of the drifts and shafts and evolution of the excavation damage zone (EDZ) were investigated for the loading conditions expected for the period of one million years, including in-situ stresses, time-dependent strength degradation, low-probability seismic ground motions and loading of glacial ice sheet. The completed geomechanical modeling study is a part of the geosynthesis work program aimed to demonstrate that the proposed layout and geometry satisfy stability and safety requirements.

Investigated long-term stability of different design concepts for high-level nuclear waste deep geological repository (DRG) in Canada. Two geological settings were analyzed: crystalline and sedimentary rocks. Stability of placement rooms and damage in the surrounding rock mass were analyzed for period of 1,000,000 years considering expected loading conditions and perturbations including: in-situ stresses, temperature changes due to heat released by stored waste, time-dependent strength degradation, glacial loading, gas pressure and seismic loading.

Hydraulic Fracturing in Naturally Fractured Reservoirs: Developed methodologies for the simulation of hydraulic fracturing in naturally fractured reservoirs using distinct element (*3DEC* and *UDEC*) , particle flow codes (*PFC2D*) and lattice codes (XSite). Participated in a number of projects in which the methodologies were used to investigate the effect of different in-situ field conditions and operational parameters on hydraulic fracturing and the interaction between the hydraulic fracture and pre-existing fracture network. The studies were conducted for some of the largest oil and gas (e.g., Shell, BP and Conoco-Phillips) and mining (e.g., Rio Tinto) companies.

Study of Feasibility Enhanced Geothermal Systems (EGS): For U.S. DOE, managed the numerical study of feasibility of EGS. Fully coupled thermo-hydro-mechanical models (*UDEC* in 2D and *3DEC* in 3D) were used to determine the favorable in-situ conditions (e.g., fracture network characteristics, in-situ stress state and rock mass mechanical and hydraulic properties) and the optimum operational parameters (e.g., injection rate and fluid viscosity) for the EGS. The criteria for feasibility of the EGS were expressed in terms of the minimum rate of fluid production and the maximum rate of the temperature decrease of produced fluid. Both the stimulation and production phases of EGS were simulated numerically in models with discrete fracture network explicitly represented.

Numerical Modeling of Underground Nuclear Explosions: Acted as a consultant to International Geological Commission established by French government to investigate effects of underground nuclear testing on the structural stability of atolls of Mururoa and Fangataufa, French Polynesia. Responsible for numerical simulations related to deformation and stability of rock mass including: (a) near-field effects — predictions of cavity size and extent of different modes of damage in the rock mass, which involved development of the numerical model for and simulation of shock-wave propagation caused by nuclear explosion; and (b) far-field effects — effects of elastic waves caused by nuclear explosion on stability of atoll flanks and subsidence of the atoll rim.

Rock Mechanics Applied to Underground Mine Design: Involved in the investigation of mechanism of large-scale panel collapses at room-and-pillar trona mines in Green River, Wyoming. Developed a methodology that can be used to provide guidelines for safe mine design (i.e., panel spans, extraction ratio, pillar widths) accounting for interaction between pillars and overburden. Investigated using three-dimensional models of the mechanisms of movement of large blocks formed by faults at Kidd Creek Mine (Falconbridge, Timmins, Canada) and its consequences on mine operation. Suggested measures (mining sequence) to reduce the risk of additional movement and potential disruption of mine operation. Analyzed mine-scale convergence rate due to salt creep at Sifto Mine (Goderich, Canada). Involved in the design of an optimal mining methodology at De Beers' Snap Lake operation. Analyses of mine-scale deformation (looking at potential consequences of permeability change) due to different level of extraction were conducted. Effects of different pillar extraction schemes were investigated using pillar-scale models.

Rock Mechanics Applied to Stability of Open Pit Mines: As a consultant and researcher, participated in Large Open Pit (LOP) project, a research project funded by the consortium of some of the largest mining companies with an objective to resolve number of critical issues for large open pits. For LOP, managed development and validation of a new code for stability analysis of LOP walls. Participated in the development of guidelines for calculation of pore pressures and their consideration in stability analysis of the open pit slopes in fractured rock masses. Investigated the effect of seismic shaking on stability of open pits and assessed accuracy of approximate pseudo-static method.

Code Development: Managed the development of the implementation of Synthetic Rock Mass (SRM) in the lattice method for simulation of slope stability in fractured rock masses (Slope Model) and hydraulic fracturing in naturally fractured reservoirs (XSite). Involved in the development of different Itasca codes including a fully coupled 3D model of fluid flow through the joints in deformable media (*3DEC*), a new algorithm (fast flow) for simulating hydro-mechanical coupling in porous media (*FLAC*), and mixed discretization in *3DEC*; continuum and micro-mechanical constitutive models (*FLAC, PFC*).

Tool-Rock Interaction: Theoretical and numerical analyses of rock cutting; determination of cut-ability criterion as a function of the material properties of the rock, geometry of the tool and cutting disposition; determination of ductile to brittle transition; prediction of force required to induce fracturing of the rock during tool indentation (University of Minnesota, Department of Civil Engineering).

Underground Storage of Hydrocarbons: U.S. DOE review of new technology for the underground storage of gas under large pressure into lined rock caverns (LRC). New technology promises to provide additional flexibility in meeting seasonal fluctuations in energy demands. Complex three-dimensional structure-rock interactions were investigated to determine the most unfavorable conditions for the operation of the structure. Design and consulting related to aqua-type underground oil-storage facilities: analytical and numerical analysis of the stability of caverns; design of primary and permanent support of underground excavations; simulation of the influence of underground storage systems on regional groundwater conditions during construction and operation. (Energoprojekt).

Design of Dams: Consultant to the project manager for the stability of slopes and underground excavations during construction at the Bekhme Dam, Iraq; development and programming of analytical and numerical procedures (finite-element method) used in analysis of stability and design of support of slopes and underground excavations in rock (Energoprojekt).