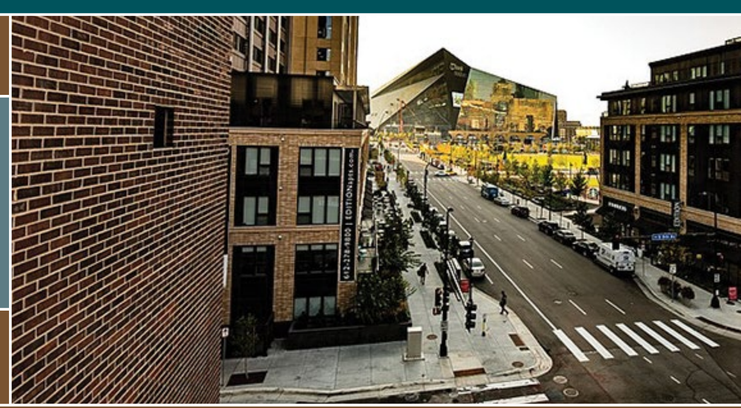
Geo-Congress 2020

GSP 321

University of Minnesota 68th Annual Geotechnical Engineering Conference



Selected Papers from the Geo-Congress 2020
Minneapolis, Minnesota
February 25–28, 2020

Edited by

Joseph F. Labuz, Ph.D., P.E.; Brent A. Theroux, P.E.;
James P. Hambleton, Ph.D.; Roman Makhnenko, Ph.D.;
and

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American Society of Civil Engineers

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Preface

This is the 68th offering of the University of Minnesota Annual Geotechnical Engineering Conference, which was started in 1953, largely through the efforts of Miles Kersten, University of Minnesota; Charles Britzius, Twin City Testing; C.K. Preus, Minnesota Highway Department; and Wilfred Darling, Corps of Engineers. The speakers at the 1st conference included Kersten, Britzius, and Preus, as well as Herbert Wright, University of Minnesota; Rockwell Smith, Association of American Railroads; and Ralph Peck, University of Illinois. In 1979, at the 27th conference, the Kersten Lecture was established and George Sowers, Georgia Institute of Technology, presented the first lecture.

The tradition continues through the Planning Committee, whose members represent the contracting industry, government agencies, consulting engineers, and the University, with a program offering technical information and discussion on recent projects for the geoengineering community. Topics at the 68th conference cover energy geotechnology, numerical modeling in geomechanics, lessons learned from failures, waste on-site disposal, and case histories. The conference provides a forum to interact with peers, meet specialty contractors, and hear researchers and practitioners discuss theory and application of geomechanics.

This volume is one of seven containing the full collection of papers presented at Geo-Congress 2020, numbering well of 400 in total. Each of the seven volumes were reviewed in accordance with ASCE GSP standards. Each paper was subjected to technical review by two or more independent peer reviewers, and publication required concurrence by at least two peer reviewers. These publications and the conference itself would not have been possible without the diligent effort of the individuals recognized in the acknowledgements.

The Editors,

Joseph Labuz, Ph.D., P.E., F.ASCE, University of Minnesota
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Geo-Congress 2020 and its published proceedings would not have been possible without the diligent, coordinated effort of numerous people, especially the reviewers who provided detailed feedback on papers and the session chairs who made decisions and provided editorial assistance on selected topics. The reviewers recognized below provided assistance specifically with the papers in this special volume. The editorial team is also profoundly grateful to Mr. Derrick Dasenbrock (Conference Chair), Dr. Roman Hryciw (Technical Program Co-Chair), Dr. Nick Hudyma (Technical Program Co-Chair), Dr. Nima Goudarzi, Mr. Brad Keelor, Ms. Erin Ryan, and the ASCE publications team for their crucial roles in the production of these proceedings.

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Contents

The Art of Numerical Modeling in Geomechanics

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ABSTRACT

Numerical modeling is used extensively in the design and evaluation of projects that involve the behavior of rock, soil, and groundwater. There are many potential pitfalls for the modeler, particularly if inexperienced, some of which are discussed. The importance of understanding mechanisms is stressed, and this point is illustrated with examples that show the advantages of building simplified models in addition to detailed models for site analysis.

INTRODUCTION

Numerical modeling is used widely to understand and predict the behavior of soil, rock and coupled fluids in the fields of mining, geothermal, petroleum and civil engineering. Typical methods are finite elements, finite volume, boundary elements and discrete elements.

Although these calculation schemes are based on mathematical formulations, and thus may be expected to be subject to scientific methodology, there is an art involved in the effective application of numerical models in engineering.

The author was involved in helping users of Itasca codes (*FLAC*, *UDEC*, *PFC*, etc.) for many years and has seen many incorrect usages and inappropriate approaches to modeling, as well as opportunities that have been missed for understanding mechanisms that characterize the behavior of rock, soil and coupled fluid in geomechanical applications. Drawing on these experiences, an attempt is made to formulate some suggestions for successful and informative modeling.

UNDERSTANDING MECHANISMS

We believe that the most important aspect of any engineering project is to understand the dominant mechanisms that determine the system's behavior. If a model is too complicated, the mechanisms may not be obvious, so it is worth constructing simple models first, driven by the questions that the models are supposed to answer. This approach was recommended by Cundall and Starfield (1988) and reinforced by Detournay et al. (1993) and Hammah and Curran (2009). As Albert Einstein said, "Everything should be made as simple as possible, but not simpler." A hierarchy of models of increasing complexity is also useful for showing how each added feature contributes to the behavior. Two examples are presented that use simple models to explain mechanisms that occur in complex models.

Displacements arising from fluid impoundment behind an arch dam: Consider the question of water seepage from the filling of a reservoir behind a large arch dam. The question we wish to answer is: Will the river banks experience convergence, and over what time scales will they occur? Most large dams are constructed in complex geological environments with irregular topography for the dam placement and reservoir. A model with all this complexity in place is not only time-consuming to run, but the dominant mechanisms are likely to be obscured. The simplest model is two-dimensional elastic, showing how water emplacement in an idealized valley leads to short- and long-term displacements. Figure 1 shows an upstream cross-section of an idealized valley with impounded water, where the colors denote layers of different rock types. In the short term (without fluid migration into the rock), the mechanical response of the saturated valley is depicted in Figure 2 by vectors and contours of horizontal displacements. There is a downwards and inwards movement that may be termed the "mattress effect," noting that a load applied to the surface of a mattress causes surface displacements towards the load. After the fluid flow has reached steady state at some time, the incremental displacements (due to fluid migration alone) are depicted in Figure 3. The horizontal displacements are outwards from the valley, due to expansion induced by increases in fluid pressure (see Figure 4 for contours of excess pore pressure). Thus, the short-term and long-term valley convergence contributions are opposite in sign. In the simple example, the former is greater than the latter, but in a more realistic model, this order may be reversed. However, the mechanisms revealed by the simple model have given us something to watch out for in more complex models.

It might be tempting to simplify the model further and consider water impoundment over a 1D saturated column. However, no induced displacement would be predicted in this case, since the increase in total stress would balance the increase in fluid pressure. This would be an example of over-simplifying.

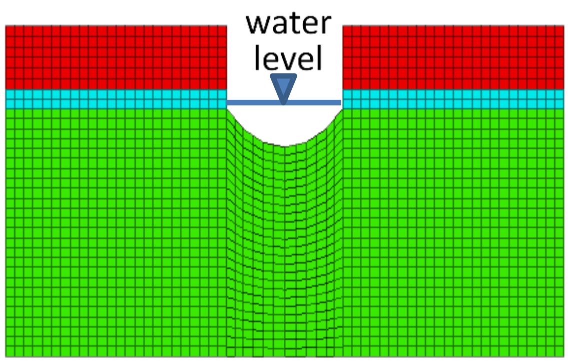

Figure 1. 2D model of idealized valley, with rock layers and water level.

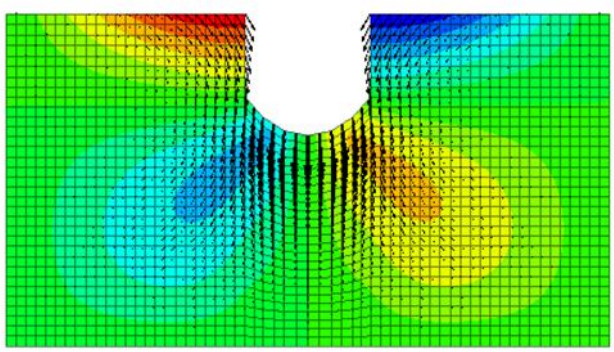

Figure 2. Displacement vectors and horizontal displacement contours for short-term response (no fluid migration). The maximum inward displacement is 12 mm.

Hydraulic fracture interaction: In the second example, we consider the interaction of two hydraulic fractures. The code *XSite* (Cundall 2011; Itasca 2019) uses a lattice of springs and masses to represent a brittle material that may develop macroscopic fractures that consist of chains of spring breakages, each of which is regarded as a micro-fracture. Each broken spring has a fluid pressure node associated with it, and neighboring nodes are linked by "pipes" that