

INTERPRETING EXCAVATION-INDUCED DISPLACEMENTS AROUND  
A TUNNEL IN HIGHLY STRESSED GRANITE

BY

RODNEY STEWART READ

A Thesis  
Submitted to the Faculty of Graduate Studies  
in Partial Fulfillment of the Requirements  
for the Degree of

DOCTOR OF PHILOSOPHY

Department of Civil and Geological Engineering  
University of Manitoba  
Winnipeg, Manitoba

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ISBN 0-315-99059-7

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# Abstract

In concepts for the underground storage of nuclear fuel waste, the primary rock mechanics concern is the development of damage around excavations. By controlling the extent of the excavation damage zone, the potential for transport of radionuclides, either by diffusion or by groundwater flow within this zone, can be controlled. To this end, it is first necessary to demonstrate that the fundamental behaviour of the rock mass around underground openings is understood. The measurement and interpretation of excavation-induced displacements around openings plays a key role in this respect. For example, in the absence of appreciable excavation-induced damage, displacements have been used extensively to back calculate *in situ* stresses. In rock damaged during excavation, displacement measurements, in combination with numerical models and *in situ* characterization, are also important as a means of determining the extent and characteristics of the damaged zone, and the processes responsible for its development. These two applications tend to be mutually exclusive.

Using AECL's Mine-by Experiment as the field study, this thesis considers the problems associated with analysis and interpretation of displacement measurements taken during excavation of a cylindrical tunnel in a massive, highly stressed, brittle rock mass. A technique using the radial displacement response from within one diameter of the tunnel face is developed to back analyze the *in situ* stress tensor in conditions where extensive excavation damage is evident in parts of the tunnel. The estimated stress tensor is, in turn, used in conjunction with observations and results from field characterization, and numerical modeling, to determine the extent and characteristics of excavation damage around the tunnel. The

relationship between displacement, stress and excavation damage is also explored through comparison of results from numerical modeling and field characterization.

The main contributions represented by this thesis are:

- An *in situ* stress back analysis technique based on radial displacement measurements taken within one tunnel diameter of the face.
- General approximating functions to describe the relationship between radial displacement and tunnel face position (i.e., the *spliced logistic function*), and between radial displacement and radial distance for positions within one diameter of the tunnel face.
- Parametric functions describing the *characteristic radial displacement surfaces* associated with components of a partitioned unit stress tensor.
- An interpretative methodology for displacement measurements in highly stressed brittle rock, including a correction methodology for face curvature and stepped longitudinal tunnel geometry.
- An assessment of the limitations of posterior-type displacement monitoring instruments, such as convergence arrays, and the assumptions inherent in interpreting results from them.
- An estimate of *in situ* stress conditions and material properties at the 420 Level of AECL's Underground Research Laboratory.
- An interpretation of the extent and characteristics of the damaged zone around the Mine-by Experiment test tunnel, and the processes responsible for its development.

# Acknowledgements

I would first like to thank my wife, Angel, for her tireless support and encouragement through a very hectic period of our lives involving the births of our two sons, Joshua and Kieran. Without her and our shared faith, this work would not have come to fruition.

This thesis represents a culmination of ideas and experiences from what can only be described as a remarkable research environment in which to work. I am indebted to AECL Research for the financial support provided to pursue graduate studies at the University of Manitoba, and to Gary Simmons and Derek Martin for the opportunity to serve as Principal Investigator for the Mine-by Experiment. I would also like to express sincere thanks to Neil Chandler for many interesting and insightful conversations.

I am grateful to my parents for their support in this and all of my academic pursuits. Their long-distance interest helped motivate me when the task of putting pen to paper seemed too daunting to undertake. My sister, Linda, also provided incentive to complete this project.

Finally, I would like to thank my advisor, Brian Stimpson, and examination committee for their guidance and recommendations that have helped steer this thesis in its evolution. Their comments and criticism provided impetus when the creative wheels sometimes needed greasing.

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