Interpreting Excavation-Induced Displacements around a Tunnel in Highly Stressed Granite

By

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

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A Thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

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.

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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.

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