

RODNEY STEWART READ, Ph.D., P.Eng., P.Geol.

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SYNOPSIS

Dr. R.S. (Rod) Read, P.Eng., P.Geol. is President of RSRead Consulting Inc., a Canadian engineering consulting firm specializing in applied rock mechanics and geotechnical engineering. Dr. Read has over 27 years of experience in projects related to nuclear waste disposal, petroleum geomechanics, pipeline and railway geotechnics, rock and soil slopes, and civil structures. This experience includes planning and management of multi-disciplinary projects and experimental programs for nuclear waste management organizations, geotechnical research for nuclear waste disposal, application of instrumentation and monitoring systems, geotechnical hazard assessment and remediation, geomechanical analysis of pipeline and petroleum-related processes, rock mechanics and slope stability analysis, surface and underground geotechnical characterization, design and analysis of underground excavations, and construction supervision.

Between 1987 and 1997, Dr. Read was Principal Investigator and or Experiment Manager for several large multi-disciplinary in-situ investigations at AECL's Underground Research Laboratory (URL), including the Mine-by Experiment, the Heated Failure Tests, the Excavation Stability Study, and the Thermal-Mechanical Stability Studies. These investigations studied fundamental issues associated with rock mass response to excavation and heating, including tunnel instability and excavation damage zone (EDZ) development.

Since 1997, Dr. Read has provided consulting services to clients in the civil, petroleum, transportation, and energy sectors. He has consulted to AECL, Ontario Power Generation, and several international organizations in regards to geomechanics and monitoring issues associated with nuclear waste disposal. Recent studies include an exhaustive summary of EDZ findings from international programs, a detailed description of Features, Events and Processes (FEPs) related to geology and/or rock mechanics, and planning of large-scale laboratory testing to investigate the issue of rock shear effects on emplaced waste containers. Other recent projects have included geohazard assessment of pipelines in arctic and tropical environments, as well as geohazard assessment, geotechnical monitoring system design, and project engineering for the Turtle Mountain Monitoring Project in Crowsnest Pass, Alberta – the site of the 1903 Frank Slide. Dr. Read has also been involved in a number of civil and petroleum-related projects including the Mackenzie Gas Project, the Oldman River Dam Project, and the St. Mary's Dam spillway replacement project.

Dr. Read is experienced in the application of FLAC and other numerical codes to conduct complex analyses, and has managed diverse field characterization and laboratory testing programs. He is a member of several professional organizations, and is registered as a Professional Engineer in British Columbia and Manitoba. He carries dual registration as a Professional Engineer and Professional Geologist in Alberta. Since 1987, Dr. Read has authored or co-authored over 100 published articles and reports on various technical aspects of his work, and has received awards from the Tunnelling Association of Canada and the Association of Professional Engineers of Manitoba. RSRead Consulting Inc. operates from its main office in Okotoks, Alberta and a field office in Revelstoke, BC.

EDUCATION	<i>Post-Secondary</i>	Ph.D. (1994), Department of Civil & Geological Engineering University of Manitoba, Winnipeg, MB, Canada
		B.A.Sc. (1984), Department of Geological Engineering University of British Columbia, Vancouver, BC, Canada
PERSONAL	<i>Nationality</i>	Canadian
	<i>Birthdate</i>	April 22, 1961 (Revelstoke, BC, Canada)
AWARDS	1997	Association of Professional Engineers of the Province of Manitoba's Early Achievement Award
	1996	Short-listed in 1996 International Society for Rock Mechanics (ISRM) Rocha Medal thesis competition
	1995	First Prize in Tunnelling Association of Canada (TAC) Graduate Student Thesis Award competition
	1995	Nominated for Natural Sciences and Engineering Research Council of Canada (NSERC) Doctoral Prize competition
WORK EXPERIENCE	1983	George E. Winkler Memorial Scholarship
	2000 – Present	President and Principal Consultant, RSRead Consulting Inc., Okotoks, AB Principal consultant focused on geohazard assessment, geomechanical analysis, geotechnical engineering related to nuclear waste disposal, railway and pipeline geotechnics, instrumentation, slope stability analysis, rock mechanics research and development, and project/program planning and management. Contractor to WorleyParsons for the Mackenzie Gas Project and the Alaska Pipeline Project involved in right-of- way preparation planning, uplift resistance testing and analysis, and other geotechnical issues associated with the project.
	2000 – 2001	Senior Geomechanics Engineer / Manager, Geotechnical Advanced Geotechnology Inc., Calgary, AB Senior geomechanics engineer and geotechnical engineering manager specializing in project planning, analysis, and numerical modelling related to petroleum production, heavy oil extraction using SAGD and other thermal processes, borehole stability, in situ stress determination, site characterization, and application of microseismic and geotechnical monitoring technology.
	1998 – 2000	Senior Geotechnical Engineer, BGC Engineering Inc., Calgary, AB Senior geotechnical engineer specializing in geomechanics- related projects. Typical projects: coordination and technical direction of thermal-mechanical stability studies at AECL's Underground Research Laboratory; geotechnical engineering gap analysis and project planning for Ontario Power Generation's Used Fuel Disposal Technology Program; numerical analysis of slope stability and soil/pipeline interaction; stability assessment of directionally-drilled boreholes; railway rock slope stabilization; foundation investigation.

**WORK
EXPERIENCE
(cont.)**

- 1997 - 1998 **Senior Geotechnical Engineer,
Klohn-Crippen Consultants Ltd., Calgary, AB**
Senior geotechnical engineer specializing in rock mechanics-related projects. Typical projects: analysis and interpretation of results from geotechnical research at AECL's Underground Research Laboratory; assessment of instrumentation and rock bolt performance in spillway replacement project at St. Mary dam; analysis of drainage criteria; project management of geotechnical site investigations.
- 1987- 1997 **Geomechanics Research Engineer,
AECL, Underground Research Laboratory, MB**
Senior rock mechanics engineer for Geotechnical Science & Engineering Branch. Design, project management/ coordination, contract administration, analysis and reporting related to geomechanics research conducted to support the Canadian Nuclear Fuel Waste Management Program and Ontario Hydro's Used Fuel Disposal Project. Experiment Manager and Principal Investigator for the Mine-by Experiment, one of the world's foremost rock mechanics experiments addressing issues related to the Canadian concept for nuclear fuel waste disposal. Specialist in fundamental rock mechanics research related to tunnel design and excavation-induced damage for several large experiments, including the Tunnel Sealing Experiment, Excavation Stability Study, Heated Failure Tests and In Situ Characterization program.
- 1985 - 1987 **Geotechnical Engineer,
Golder Associates, Vancouver, BC**
Project engineer on various geotechnical projects including the Oldman River Dam site investigation and test diversion tunnel project in Alberta; quarry investigation in the NWT; Cigar Lake mine study in Saskatchewan; and other civil projects.
- 1984 - 1985 **Engineer-in-Training,
CP Rail Special Projects, Revelstoke, BC**
Supervision of twinning of the Rogers Pass section of the CP mainline including aspects of rock and soil engineering design, concrete testing, and contract administration.
- 1979 - 1984 **Summer Student,
BC Hydro, Ministry of Highways, CP Rail, Revelstoke, BC**
Various engineering-related positions to support undergraduate studies.

**PROFESSIONAL
AFFILIATIONS**

- 2002 – present Registered Professional Geologist, Alberta (APEGGA)
2002 – present Registered Professional Engineer, British Columbia (APEGBC)
2000 – present Member, Petroleum Society of CIM, Alberta
1997 – present Registered Professional Engineer, Alberta (APEGGA)
1987 – present Registered Professional Engineer, Manitoba (APEGM)
1998 – 1999 Adjunct Professor, Dept. of Civil Engineering, University of Calgary
1999 – present Member, American Rock Mechanics Association
1998 – present Member, International Society for Rock Mechanics (ISRM)
1998 – present Member, Canadian Geotechnical Society (CGS)
1998 – 1999 Committee Member, Calgary Chapter of CGS
1989 – present Member, Tunnelling Association of Canada (TAC)
1984 – 1987 Engineer-in-training, (APEBC)
1984 – 1987 Member, Vancouver Geotechnical Society

Books and Journal Publications

- Rizkalla, M., R.S. Read, and G. O'Neil. 2008. Pipeline Geo-Environmental Design and Geohazard Management. Chapter 6 Geohazard Management. ASME, 352 pp.
- Read, R.S. 2004. 20 years of excavation response studies at AECL's Underground Research Laboratory. *Int. J. Rock Mech. & Min. Sci.* 41: 1251-1275.
- Eberhardt, E., D. Stead, B. Stimpson, and R. Read. 1998. Identifying crack initiation and propagation thresholds in brittle rock. *Can. Geotech. J.*, **35(2)**: 222-233.
- Read, R.S., N.A. Chandler, and E.J. Dzik. 1998. In situ strength criteria for tunnel design in highly-stressed rock masses. *Int. J. Rock Mech. & Min. Sci.*, **35(3)**: 261-278.
- Maxwell, S.C., R.P. Young, and R.S. Read. 1998. A microvelocity logging tool to assess the excavation damaged zone. *Int. J. Rock Mech. & Min. Sci.*, **35(2)**:235-247.
- Eberhardt, E., D. Stead, B. Stimpson, and R.S. Read. 1997. Changes in acoustic event properties with progressive fracture damage. *Int. J. Rock Mech. & Min. Sci.*, **34**:3-4, Paper No. 071B.
- Martin, C.D., R.S. Read, and J.B. Martino. 1997. Observations of brittle failure around a circular test tunnel. *Int. J. Rock Mech. & Min. Sci.*, **34(7)**: 1065-1073.
- Martin, C. Derek, Neil A. Chandler, and Rodney S. Read. 1996. The role of convergence measurements in characterizing a rock mass. *Can. Geotech. J.*, **33**: 363-370.
- Martino, Jason B., and Rodney S. Read. 1996. An overview of AECL's Heated Failure Tests. *ISRM Newsjournal*, **4(1)**: 24-31.
- Read, R.S., and C.D. Martin. 1991. The Underground Research Laboratory Mine-by Experiment - A research perspective on tunnel design. *Canadian Tunnelling*, **7**:75-88.
- Read, R.S., S.C. Maxwell, and R.P. Young. In prep. Characterizing excavation damage around tunnels using micro-velocity measurements - an example from AECL's Underground Research Laboratory. *Int. J. Rock Mech. & Min. Sci.*
- Read, Rodney S. In prep. Back analysis of 3D stresses from radial displacements near the face of a single circular tunnel. *Int. J. Rock Mech. & Min. Sci.*

Conference Publications

- Read, R.S., Birch, K. 2008. The role of rock engineering in developing a deep geological repository in sedimentary rocks. ROCKENG09: Proceedings of the 3rd CANUS Rock Mechanics Symposium, Toronto, May 2009 (Ed: M.Diederichs and G. Grasselli), Paper 4146.
- Read, R.S., Birch, K. 2008. Reasoned argument why large-scale fracturing will not be induced by a deep geological repository. ROCKENG09: Proceedings of the 3rd CANUS Rock Mechanics Symposium, Toronto, May 2009 (Ed: M.Diederichs and G. Grasselli), Paper 4147.
- Rizkalla, M., and R.S. Read. 2007. The assessment and management of pipeline geohazards. Paper IBP1205_07. In Proc. Rio Pipeline 2007 Conference and Exposition, Rio de Janeiro, Brazil.
- Read, R.S., W. Langenberg, D. Cruden, M. Field, R. Stewart, H. Bland, Z. Chen, C.R. Froese, D.S. Cavers, A.K. Bidwell, C. Murray, W.S. Anderson, A. Jones, J. Chen, D. McIntyre, D. Kenway, D.K. Bingham, I. Weir-Jones, J. Seraphim, J. Freeman, D. Spratt, M. Lamb, E. Herd, D. Martin, P. McLellan, & D. Pana. 2005. Frank Slide a Century Later: The Turtle Mountain Monitoring Project. In Proc. of the International Conference on Landslide Risk Management, Vancouver, B.C. Canada. Balkema Publishers, Netherlands. pp. 713-723.

- Froese, C.R., Murray, C.M., Cavers, D.S., Anderson, W.S., Bidwell, A.K., Read, R.S., Cruden, D.M., & Langenberg, W. 2005. The development of a warning system for the South Peak of Turtle Mountain. Proceedings of the International Conference on Landslide Risk Management, Vancouver, B.C. Canada. Balkema Publishers, Netherlands. pp. 705-712.
- Read, R.S. 2003. A framework for monitoring the South Peak of Turtle Mountain - the aftermath of the Frank Slide. In Proc. 3rd Canadian Conference on Geotechnique and Natural Hazards, Edmonton, Alberta, Canada June 9 - 10, 2003. pp 261-268.
- Read, R.S.. 2003. The role of tunnel design in controlling excavation damage development. Presented at EURATOM CLUSTER Conference, Nov 2004, Luxembourg.
- Read, R.S. and J.B. Martino. 2002. To arch or not to arch – the role of tunnel design in controlling excavation damage development. In *Proc. of the EDZ Workshop, NARMS-TAC 2002, July 6, 2002, Toronto, Ontario, Canada.*
- Chandler, N.A., J.B. Martino, and R.S. Read. 2002. The EDZ exists – So what? In *Proc. of the EDZ Workshop, NARMS-TAC 2002, July 6, 2002, Toronto, Ontario, Canada.*
- Isherwood, A., K.W. Savigny, A. Samchek and R.S. Read. 2002. Deformation analysis of a pipeline river crossing. Proc. IPC 2002: International Pipeline Conference, Sept 29 – Oct 3, 2002, Calgary, Alberta, Canada.
- Chandler, N.A., R.S. Read, D. Potyondy, R.P. Young, and J. Hazzard. 2002. Computing brittle rock fracture and excavation stability using the Particle Flow Code. In *Proc. 2nd Canadian Specialty Conference on Computer Applications in Geotechnique, April 28-30, 2002. Winnipeg, Manitoba, Canada.*
- McLellan, P.J., C.D. Hawkes, and R.S. Read. 2000. Sand production and control in horizontal wells for gas-storage reservoirs. In *Proc. 4th International Conference and Exhibition on Horizontal Well Technology, Nov. 6-8, Calgary AB.*
- McLellan, P.J., R.S. Read, and K. Gillen. 2000. Assessing caprock integrity for steam assisted gravity drainage projects in heavy oil reservoirs. In *Proc. 4th International Conference and Exhibition on Horizontal Well Technology, Nov. 6-8, Calgary AB.*
- Chandler, N.A., R. Read, P. Cundall, D. Potyondy, E. Detournay, R.P. Young, and J.S.O. Lau. 2000. An integrated approach to excavation design – a project within Canada's used fuel disposal program. In *Proc. 4th North American Rock Mechanics Symposium, Seattle, WA, pp. 1271-1278.*
- Read, R.S., and N.A. Chandler. 2000. Linkage between performance assessment, repository design and site characterization – a Canadian perspective. In *Proc. 2nd International Workshop on Geomechanics of Nuclear Waste Repositories, July 2000, Seattle, WA.*
- Read, R.S., K.W. Savigny, F. Oboni, D.M. Cruden, and W. Langenberg. 2000. Geotechnical hazard assessment of the south flank of Frank Slide. In *Proc. GeoCanada 2000, Calgary, AB.*
- Read, R.S., and N.A. Chandler. 1999. Excavation damage and stability studies at the URL - rock mechanics considerations for nuclear fuel waste disposal in Canada. In *Proc. 37th US Rock Mech. Symp., Vail, CO: Balkema: Rotterdam, pp. 861-868.*
- Chandler, N.A., and R.S. Read. 1998. The long-term behaviour of excavations in granite - In situ evidence from Canada's URL and implications for waste retrieval. In *Proc. International Workshop on Reversibility, Paris, ANDRA.*
- Leite, Maria Helena, Robert Corthèsy, Denis E. Gill, and Rodney Read. 1997. Some aspects of a stress calculation model for deep measurements using the modified doorstopper cell. In *Proc. Int. Symp. on Rock Stresses, Kumamoto, Japan: Balkema:Rotterdam, pp. 65-70.*
- Read, R. S., and N. A. Chandler. 1997. Minimizing excavation damage through tunnel design in adverse stress conditions. In *Proc. 23rd General Assembly - Int. Tunnel. Assoc., World Tunnel Congress '97, Vienna. Balkema: Rotterdam, pp. 23-28.*
- Read, R. S. 1996. Characterizing excavation damage in highly-stressed granite at AECL's Underground Research Laboratory. In *Proc. Int. Conf. on Deep Geological Disposal of Radioactive Waste, EDZ Workshop, Winnipeg, pp. 35-46.*

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- Read, R. S. 1996. Rock mechanics research at AECL's Underground Research Laboratory - An overview. In *Prog. Symp. on Contributions to Geology by the Canadian Nuclear Fuel Waste Management Program, Winnipeg*, p. A-78.
- Read, R. S., and J. B. Martino. 1996. Effect of thermal stresses on progressive rock failure at AECL's Underground Research Laboratory. In *Proc. Int. Conf. on Deep Geological Disposal of Radioactive Waste, Winnipeg*, pp. 7-43 - 7-53.
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- Martin, C. Derek, and Rodney S. Read. 1996 AECL's Mine-by Experiment: A test tunnel in brittle rock. In M. Aubertin, F. Hassani, and H. Mitri, editors, *Proc. 2nd North American Rock Mech. Symp., Montreal*: Balkema: Rotterdam, pp. 13-24.
- Chandler, Neil A., Rodney S. Read, and C. Derek Martin. 1996. In situ stress measurements for nuclear fuel waste repository design. In M. Aubertin, F. Hassani and H. Mitri, editors, *Proc. 2nd North American Rock Mech. Symp., Montreal*: Balkema:Rotterdam, pp. 929-936.
- Chandler, Neil A., Rodney S. Read, and Alan W. L. Wan. 1996. Implications of the results of URL experiments on the design of repository seals in granite. In *Proc. Int. Conf. on Deep Geological Disposal of Radioactive Waste, Winnipeg*, pp. 7-1 - 7-10.
- Hayles, J.G., M.H. Serzu, G.S. Lodha, and R.S. Read. 1996. Cross-hole seismic tomography for the Mine-by Experiment. In *Proc. Soc. Expl. Geophysicists Int. Exposition, Denver*, Vol. 1, pp. 904-907.
- Lodha, G.S., J.G. Hayles, G.W. Kuzyk, and R.S. Read. 1996. Review of geophysical techniques used for understanding rock mass damage with examples from controlled experiments at the Underground Research Laboratory, Pinawa, Manitoba, Canada. Presented at *FRAGBLAST '96 Conference, Montreal*.
- Read, Rodney S., C. Derek Martin, and Edward J. Dzik. 1995. Asymmetric borehole breakouts at the URL. In J. Daemen and R. Schultz, editors, *Proc. 35th U.S. Rock Mech. Symp., Lake Tahoe*: Balkema: Rotterdam, pp. 879-884.
- Martin, C.D., R.S. Read, and E.J. Dzik. 1995. Near-face cracking and strength around underground openings. In H. P. Rossmanith, editor, *Proc. 2nd Int. Conf. on Mechanics of Jointed and Faulted Rock, Vienna*: Balkema: Rotterdam, pp. 747-752.
- Martin, C.D., N.A. Chandler, and R.S. Read. 1994. The role of convergence measurements in characterizing a rock mass. In *Proc. 47th Can. Geotech. Conf., Halifax*, pp. 408-417.
- Read, R.S., and C.D. Martin. 1992. Monitoring the excavation-induced response of granite. In J. R. Tillerson and W. R. Wawersik, editors, *Proc. 33rd U.S. Symp. on Rock Mech., Santa Fe*: Balkema: Rotterdam, pp. 201-210.
- Martin, C.D., and R.S. Read. 1992. The *in situ* strength of massive granite around excavations. In P. K. Kaiser and D. McCreath, editors, *Proc. 16th Can. Rock Mech. Conf., Sudbury*, pp. 1-10.
- Thompson, P.M., B.H. Kjartanson, and R.S. Read. 1992. Design and construction of two major experiments at the URL. In *Proc. 1992 International High-Level Radioactive Waste Management Conference, Las Vegas, NV, Vol. 1*, pp. 1082-1089.
- Onagi, D.P., R.S. Read, and G.W. Kuzyk. 1991. AECL's Mine-by Experiment - from concept to construction. In *Proc. SME Conference, Denver*.
- Read, R.S., and C.D. Martin. 1990. The Underground Research Laboratory Mine-by Experiment - A research perspective on tunnel design. In *Proc. 8th Canadian Tunnelling Conf., Vancouver, BC*: BiTech: Vancouver, pp. 213-226.
- Martin, C.D., R.S. Read, and P.A. Lang. 1990. Seven years of *in situ* stress measurements at the URL - An overview. In W. A. Hustrulid and G. A. Johnson, editors, *Proc. 31st U.S. Symp. Rock Mech., Golden, CO*: Balkema: Rotterdam, pp. 15-26.

Martin, C.D., R.S. Read, and N.A. Chandler. 1990. Does scale influence in situ stress measurements? - Some findings at the Underground Research Laboratory. In A. Pinto da Cunha, editor, *Proc. 1st Int. Workshop on Scale Effects in Rock Masses, Loen, Norway*, Balkema: Rotterdam, pp. 307-316.

NWMO, AECL and Other Publications

Read, R.S. 2010. Rock mechanics features, events, and processes for a used fuel deep geologic repository in crystalline rock. Nuclear Waste Management Organization Technical Report NWMO TR-2010-???. (in press)

Read, R.S. 2009. Implications of excavation damage for design and performance of repository excavations and sealing systems. Nuclear Waste Management Organization Technical Report NWMO TR-2009-???. (in press)

Read, R.S. 2008. Developing a reasoned argument that no large-scale fracturing or faulting will be induced in the host rock by a deep geological repository. Nuclear Waste Management Organization Technical Report NWMO TR-2008-14.

Read, R.S. 2008. The role of rock engineering in developing a deep geological repository in sedimentary rock. Nuclear Waste Management Organization Technical Report NWMO TR-2008-16.

Read, R.S. and N.A. Chandler. 2002. An approach to excavation design for a nuclear fuel waste repository – the Thermal-Mechanical Stability Study final report. UFDP Report 06819-REP-01200-10086-R00.

Read, R.S. and N.A. Chandler. 2002. Development and integration of tools for engineering design of repository sealing systems (ENDRES), Project status – March 2002. UFDP Report 06819-REP-01300-10051-R00.

Martino, J.B., N.A. Chandler, R.S. Read and C. Baker. 2002. Response of the Tunnel Sealing Experiment concrete bulkhead to pressurization. Ontario Power Generation Report No. 06819-REP-01200-10085-R00.

Read, R.S. and N.A. Chandler. 2001. Engineering design of repository sealing systems (ENDRES) project plan. Ontario Power Generation Technical Memorandum 06819(UF)-03782.04-T10.

Read, R.S., N.A. Chandler, J.B. Martino, R.P. Young, P.Cundall, D. Potyondy, J. Lau, B. Gorski, E. Detournay, and Y. Ates. 2001. The Thermal-Mechanical Stability Study: excavation design for a nuclear waste repository. Ontario Power Generation Report (in press).

Chandler, N.A., and R.S. Read. 2000. Thermal-Mechanical Stability Studies Project Status – March 2000. UFDP Report 06819-REP-01200-10030-R00.

Read, R.S. 1999. Engineering gap analysis for the Used Fuel Disposal Program – Geotechnical engineering tools and capabilities. Ontario Power Generation Report 06819-REP-01200-10010-R00.

Chandler, N.A., and R.S. Read. 1999. Thermal-Mechanical Stability Studies Project Status – 1999 March. UFDP Report 06819-REP-01200-10001-R00.

Martino, J.B., P.M. Thompson, N.A. Chandler, and R.S. Read. 1998. The in situ stress program at AECL's Underground Research Laboratory – 15 years of research (1982-1997). UFDP Report 06819-REP-01200-0053-R00.

Read, R.S., J.B. Martino, N.A. Chandler, and E.J. Dzik. 1998. Excavation stability study - analysis and interpretation of results. UFDP Report 06819-REP-01200-0028 R00.

Read, R.S., J.B. Martino, N.A. Chandler, E.J. Dzik, S. Oliver, S. Falls and R.P. Young. 1998. Analysis and interpretation of AECL's Heated failure Tests. UFDP Report 06819-REP-01200-0070-R00.

Read, R.S. 1997. Progress report on development and integration of acoustic emission/microseismic (AE/MS) technology and numerical modelling. UFDP Report 06819-REP-01200-0042 R00.

Read, R.S. 1997. Effect of rock mass quality on selection of a waste emplacement option. UFDP Report 06819-REP-01240-0003 R00.

Thompson, P.M., J.B. Martino, N.A. Chandler, and R.S. Read. 1997. Summary of the URL In Situ Stress Program. UFDP Report 06819-REP-01200-0053 R00.

- Chan, T., M. Kolar, P.A. O'Connor, N.W. Scheier, and F.W. Stanchell with contributions by C.C. Davison, L.H. Frost, B.W. Nakka, N.A. Chandler, R.S. Read, J.D. Garroni, C.I. Kitson, D.M. Leneveu, L.H. Johnson and R. Zach. 1997. Finite-Element Sensitivity Analysis of Effects of an Excavation Damage Zone on ¹²⁹I Transport from a Used CANDU Fuel Waste Disposal Repository. UFDP Report 06819-REP-01200-0022 R00.
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- Chandler, N.A., D.A. Dixon, M.N. Gray and R.S. Read. 1996. The Tunnel Sealing Experiment conceptual design report. AECL Report TSX-01.
- Dzik, E.J., and R.S. Read. 1997. Scoping analysis of bulkhead keys for the Tunnel Sealing Experiment. AECL Report TSX-06.
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- Martino, J.B., and R.S. Read. 1996. Mine-by Experiment Phase III - Heated Failure Tests: Technical progress report and summary of Stage 3. Technical Report TR-686, COG-95-202, Atomic Energy of Canada Limited.
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- Read, R.S., J.B. Martino, and J.H. Mitchell. 1994. Mine-by Experiment data summary: Part 2 - Triaxial strain cell results. Technical Report RC-1077, COG-93-353, Atomic Energy of Canada Limited.
- Martino, J.B., and R.S. Read. 1994. Mine-by Experiment Phase III -- Heated Failure Tests: Technical progress report and summary of Stage 1. Technical Report TR-652, COG-94-478, Atomic Energy of Canada Limited.
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- Read, R.S., J.B. Martino, J.H. Mitchell, and M.H. Spinney. 1994. Mine-by Experiment data summary: Part 3 - Extensometer results. Technical Report RC-1078, COG-93-354, Atomic Energy of Canada Limited.

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

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In Canada, as in many countries that employ nuclear power, the current concept for dealing with used nuclear fuel waste is deep underground disposal in crystalline rock such as granite. One of the primary concerns in this concept is the development of damage, or cracking, around excavations, which can potentially contribute to the migration of radionuclides. To address this concern, the fundamental response of the rock mass to excavating underground openings such as shafts and tunnels must be understood. The measurement and interpretation of excavation-induced displacements, i.e., movements of the rock mass as it adjusts to the introduction of a tunnel, play a key role in this respect. For example, in the absence of appreciable damage around a tunnel, measured displacements have been used to calculate the initial stresses in the rock mass. In rock damaged during excavation, displacements measured around a tunnel in known stress conditions have been used to determine the extent and characteristics of the damaged zone. These two applications tend to be mutually exclusive.

This thesis addresses the problems associated with interpreting displacements caused by excavating a cylindrical tunnel in conditions where the stresses concentrated near the opening are sufficient to damage the rock. A new technique using displacements measured near the tunnel face is developed to calculate the initial stresses in the rock mass, and is applied to a test tunnel in granite at AECL's Underground Research Laboratory (URL), where extensive damage is evident in parts of the tunnel. The displacements measured around this tunnel constitute a data set unparalleled anywhere in the world in terms of precision and quantity. The stresses estimated from these data are, in turn, used in conjunction with results from a field investigation and computer modelling to determine the extent and characteristics of damage around the tunnel, and the processes responsible for its development. It is concluded that both the initial stress state, and the extent and characteristics of damage around the excavation, can be interpreted from displacements measured around a single tunnel.

There are several original contributions to the field of rock mechanics represented by this thesis. In terms of analytical approaches, the method used to determine the initial stresses from displacements measured near the tunnel face has not been covered in the literature to this time. This approach is shown to be important in highly stressed rock masses where other stress measurement techniques do not work. The results at the 420 Level of the URL, for example, are significant in that they represent a refinement of previous stress estimates. The mathematical functions associated with this method are also new. In particular, the equations relating stresses and displacements for a cylindrical tunnel represent a significant improvement over previous relationships used for such purposes as designing tunnel support. Curvature of the tunnel face and stepped longitudinal tunnel geometry are two aspects of real tunnels that are generally overlooked in interpreting measured displacements. Both are addressed in the thesis and are shown to be important considerations. Finally, instruments installed from within a tunnel to measure rock displacements are shown to have several limitations that have not been considered in the literature. The method of interpretation presented in the thesis accounts for these limitations.

The specific interpretation, based on the estimated initial stresses, of the extent and characteristics of the damaged zone around the AECL's Mine-by Experiment test tunnel considerably enhances the fundamental understanding of the response of highly stressed granite to excavation. First, it suggests that there is a relationship between the stresses concentrated ahead of the advancing tunnel face and the eventual development of asymmetric patterns of large-scale damage, or breakouts, inside a tunnel. Second, it shows that the grain size and grain structure of the rock mass significantly influence the development of damage. Finally, it shows that excavation damage in zones of tensile stresses around the tunnel accounts for larger than expected displacements in these regions. It is of considerable interest that this tensile damage is not visible with the naked eye, but could, nonetheless, increase the potential for transport of radionuclides, either by diffusion or by groundwater flow. Identification of these regions of damage is therefore important in designing future experiments to assess the issue of radionuclide transport along engineered openings.