GeoEngineering Centre at Queen's - RMC

Newsletter 2005

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The year in review

The formation of research centres at Queen's involves a two-step process. First, provisional status is granted for a two year period, during which time the group becomes established, builds its identity, and develops a formal constitution. That constitution is then submitted to the University Senate and Principal for approval. Centres are subsequently evaluated for re-approval by the Senate every five years.

During the first part of 2004, Centre members and our Advisory Board worked with me to develop the Centre constitution, which was submitted to the Senate for consideration in the fall. Formal approval of the centre for the 2004-2009 period was granted by Principal Hitchcock early in December. In addition to explaining our vision (*see below*) and goals, the constitution provides us with clear guidance regarding the formation and operation of our Scientific Committee, made up of our fourteen Research Directors, our Associate Research Directors, and a Student Member. The Constitution broadens the membership and responsibilities of our Advisory Board, an oversight group made up of representatives from the Principal and the Deans of Research and Graduate Studies at RMC, Arts and Science, and Applied Science at Queen's, and one Research Director from each participating Department at Queen's and RMC. The new Advisory Board also includes the possibility of adding representatives from the GeoEngineering and Applied GeoScience communities beyond Kingston.

Other developments during 2004-05 included success winning further NSERC funding as well as other grant and contract income. New NSERC funds exceeding $1.25M have been won during that period (details are provided later in the newsletter), primarily for the support of graduate students. While some of these funds are for 'single investigator' projects, the majority involves research collaborations and shared infrastructure, demonstrating the benefits of our collective activities.

Congratulations to Centre members who received recognition for excellence in research, practice and education during the past year. For example, the Provincial Government announced that Premier's Research Excellence Awards have been made to Richard Brachman and Mark Diederichs, prestigious recognition for early-career scholars in Ontario that assists by providing each recipient with $150k in support for new graduate students. A highlight for me personally was being in attendance at Imperial College during March when the accomplishments of Kerry Rowe were celebrated by the British Geotechnical Association, and he delivered the 45th Rankine lecture.

Our Collaborative Graduate Program in GeoEngineering is now in its fourth year. About two thirds of our sixty or so MSc and PhD students elect to enrol in the GeoEngineering program, extending their horizons through participation in multi-disciplinary graduate courses and our weekly seminar series. Students benefit greatly from presentations made by various visiting practitioners and academics, and students taking the seminar course make one major seminar presentation each year. If you have plans to be in or near Kingston, please contact me to discuss the possibility of contributing to our seminar program. Although four weeks notice is normally required, it is often possible to make arrangements with less notice.

Very important additions to our Centre family during 2005 were Ella Take born February 14 and Julia Brachman born May 30. Congratulations to Kelly and Andy, Dara and Richard!

I would like to take this opportunity to thank all those who assisted the centre over the past year, including excellent contributions by Drs. Peter Hodson and John Cartledge (senior scholars from the Queen's community whose work on our Advisory Board has been excellent). Support from Dr. Tom Harris, Dean of Applied Science, Sheilagh Dunn, and Rob Harrap was critical to our success winning new funds from Infrastructure Canada, and Sandra Crocker and Sonja Verbeek from the VP (Research) office have also provided excellent assistance.

Please contact myself (moore@civil.queensu.ca), Jolanda (info@geoeng.ca), or any of our members if you would like to initiate interactions with us. Our website www.geoeng.ca contains more detail of our graduate program, research facilities, personnel, and projects.

Timing of our annual newsletters has changed, and the present newsletter covers the period from the Fall of 2004 until December of 2005. Subsequent newsletters will report activities during one calendar year, simplifying the reporting of events and publications.

Ian Moore,
Executive Director, GeoEngineering Centre at Queen's – RMC

The Centre's Vision is "*to be one of the world's leading GeoEngineering research teams, featuring a large, diverse group of GeoEngineering faculty, talented and energetic graduate and postdoctoral researchers, high levels of research grant and contract funding, world-class research infrastructure, and 'leading-edge' research contributions related to a wide range of theoretical and applied projects*".

NEW RESEARCH PROJECTS FUNDED BY NSERC

Over the past twelve months, we have received over $1,250,000 in new research funding from NSERC:

- Our team received two new NSERC Research Tools and Instruments Grants, one lead by Andy Take (for "A high-speed digital imaging system for experimental research on earthquakes, landslides, and impact loading") and the other by Kerry Rowe (for equipment to study "One-Dimensional Stress-Strain Behaviour of Fine-Grained Gassy Soils"). Centre members Richard Bathurst, Vicki Remenda, and Ian Moore supported these grants.
- Kent Novakowski was awarded Discovery Grant funding for his project titled "Diffusion in Bedrock Environments"
- Andy Take was awarded a Discovery Grant for a project titled "Seasonally driven fatigue of infrastructure slopes", at $115,000 a high award for a new Civil Engineering scholar in Canada.
- In November 2004, a research team lead by Ian Moore was awarded an NSERC Strategic Research Grant for the project titled "Sustaining buried pipe infrastructure using liners". The project is being conducted in collaboration with Amir Fam of Queen's, and Hanping Hong of the University of Western Ontario.
- In October 2005, Kerry Rowe and Richard Brachman received an NSERC Strategic Research Grant for the project titled "Ensuring the Long-term Performance of Geosynthetic Liners".

C.I.T.I.E.S. Project for Infrastructure Canada

Community Infrastructure Technology and Innovation Education Symposia

Late in May, the Centre was contacted by Infrastructure Canada indicating that our **'CITIES'** proposal to Infrastructure Canada's Knowledge-Building, Outreach and Awareness Program has been approved.

In October, Infrastructure Canada announced that $3.6 million in funding would be committed over the next three years as a result of the first call for proposals under the department's new Knowledge-building, Outreach and Awareness (KOA) program. This funding supports activities contributing to knowledge and awareness building on infrastructure and communities issues. The first call for proposals under the KOA program was issued in December 2004 and over 160 proposals were received, twice the anticipated number.

The Centre's CITIES project will develop a series of training and professional development courses on innovative techniques for constructing and rehabilitating civil infrastructure. The objective is to fill gaps in existing infrastructure training and development programs by transferring knowledge from the academic to the user community. From 12 to 15 courses will be developed with content adaptable to the target audiences, which include technicians, technologists and engineers working at the community level as well as contractors serving the civil infrastructure market.

We are pleased that our project was successful, since it will permit us to extend our educational and training activities well beyond our Undergraduate and Graduate programs. The project is being lead by Mark Diederichs, Jean Hutchinson and Ian Moore together with support from Rob Harrap, Richard Bathurst, Kerry Rowe and others. Canada invests more than $40B each year repairing our aging Civil Infrastructure, and this new project extends the Centre's contributions to educational and training activities associated with this challenge significantly beyond the GeoEngineering Graduate program. The project will lead to interactions with practicing municipal engineers, consultants and construction engineers and technologists to improve infrastructure management, replacement, and repair using new technologies.

(with input from www.infrastructure.gc.ca/research-recherche/rko/fundecs/koarnd1_e.shtml)

CURRENT RESEARCH

Ground Fall Mitigation Capability and Enhanced Testing for Rockburst Susceptibility of Rock Liners (WSIB Research Project 03 010)

By James F. Archibald, Department of Mining Engineering

This research project has concentrated upon workplace design relating to underground mine support as a means of enhancing worker safety against rock falls. A large percentage of current underground worker injuries occur as the result of falls of loose rock and from worker contact with ejected rock fragments that are created during violent rock failure events, called rockbursts. Because future mining development in this province is expected to take place at greater depths than presently mined, the incidence of rock falls and rockbursts, and thus worker injuries, is projected to increase. The design and adoption of new support products and their implementation strategies are necessary components of future mining activity to help further reduce worker injury hazards and occurrences, and to provide better stabilization and support for excavations.

This research study was developed to assess the capabilities of conventional forms of mine reinforcement media and new thin, spray-on linings (TSL's) for provision of effective rock excavation structural support in underground mines. Laboratory physical characterization work, completed on eleven TSL agents, has yielded the single, most comprehensive listing of TSL structural performance properties existing worldwide. The wide range of TSL product types and physical compositions that have been investigated may benefit the mining and civil engineering industries in many ways, the least of which will be to yield greater selectivity and choice for individual site application needs. In addition, product diversity may also result in more competitive product growth, stimulate development of additional and more innovative material use, and yield reduction in material purchase costs as larger volume use and enhanced industry acceptance takes place.

Blasting trials, seen in Figure 1, were performed during this research as procedures for inducing ground motion and rock damage that is highly similar in effect to that experienced during actual underground rockburst events.

Fig. 1 – Blast-simulated rockburst event (136 milliseconds after detonation)

Dynamic ground motion effects were demonstrated to exceed minimum rockburst activity levels that have been observed within mine environments, and highly repeatable source energy outputs were maintained for all blasting trials.

Additionally, very consistent failure conditions, generating dynamic rock ejection from localized zones of fracture immediately about each blast hole, were maintained in all trials.

The wide-ranging series of tests have verified that spray-on forms of area support, including conventional concrete materials such as shotcrete and fibrecrete linings, as well as innovative TSL's and combinations of both forms of sprayable support (designated as "Superliners"), all demonstrate significant and positive benefit and abilities to resist rockburst-induced damage relative to conventional support media. The relative merits of a variety of forms of spray-on lining support materials (conventional and TSL types) for mitigating rockburst damage have been effectively demonstrated through the course of this research effort, as seen in Figure 2.

The results of laboratory tests have identified several promising TSL agent materials that may be potentially very effective in mitigating rockburst damage to both the support materials and rock surfaces onto which the materials were placed. TSL supports appear viable for reducing rockburst hazards associated with rock fracturing, fragment ejection and loss of support capacity, all conditions that are unable to be managed by conventional rock support media. It would also be anticipated that TSL support measures would realize significant support restraint in lower stress environments, where worker injury from falls of loose ground are also common.

This research has validated the assumption that new and innovative TSL supports may be equivalent to or substantially better than conventional support methods for provision of safe, sustainable support in the event of dynamic rock failure. All TSL types have demonstrated abilities to deform substantially while constraining fragment ejection created by energetic and natural rock breakage. These tenaciously-adhering cover materials have also demonstrated an ability to substantially mitigate damage often seen to result when catastrophic unsupported rock failure occurs.

Fig. 2 – Post-blast damage for unsupported and TSL-supported test sites

Unsupported rock surface *1.7 mm thick TSL layer-supported surface*

Geofoam Buffers Reduce Earthquake Loads

By Richard J. Bathurst and Saman Zarnani

Geofoam is the generic name given to expanded polystyrene (EPS) products used in geotechnical applications. These products are well known for thermal insulation and light-weight fill applications. The GeoEngineering Centre has recently completed a program of physical tests and complimentary numerical modeling to investigate these materials as seismic buffers to attenuate dynamic loads exerted against rigid wall structures during earthquake.

The physical tests were carried out using the RMC shaking table. The table is comprised of a 2.7 m by 2.7 m steel platform driven by a computer-controlled horizontally-mounted 100 kN servo-hydraulic actuator.

A typical test configuration is illustrated in *Figure 1*. The models were 1 m-high by 1.4 m-wide with a vertical EPS seismic buffer inclusion placed between the rigid wall and a uniformly graded sand backfill. Buffer materials with different modulus values were tested and the results compared to the control case with no seismic buffer. Each test was subjected to a simulated earthquake loading.

The physical tests demonstrated proof of concept. As buffer modulus decreased, peak horizontal forces on the rigid wall decreased. The reduction in peak dynamic load was as great as 40%.

Program FLAC was used to develop a model in order to numerically simulate the experimental tests. A numerical grid representing the shaking table configuration is shown in *Figure 2*. The numerical model results captured the trend in earth forces with increasing base acceleration for all three models. The numerical results were also shown to be in quantitative agreement with the relative reduction of the earthquake-induced dynamic earth forces generated against the rigid wall structures with an EPS geofoam seismic buffer compared to the control case without seismic protection (*Figure 3*).

This work is ongoing with the ultimate objective to develop design charts for the selection of geofoam seismic buffers to reduce earthquake-induced loads against basement walls and bridge abutments.

Finally, the GeoEngineering Centre is looking forward to the commissioning of a new shaking table with about 5 times the capacity of the existing table. This facility is expected to be completed in the spring of 2006 and will allow GeoEngineering Centre members to investigate the performance of larger seismic buffer models and other reinforced soil structures – some at prototype scale.

The funding for the shaking table upgrade has been provided by a CFI grant for purchase of equipment and infrastructure at Queen's and RMC to support a wide range of projects investigating the performance of geosynthetics in harsh environments.

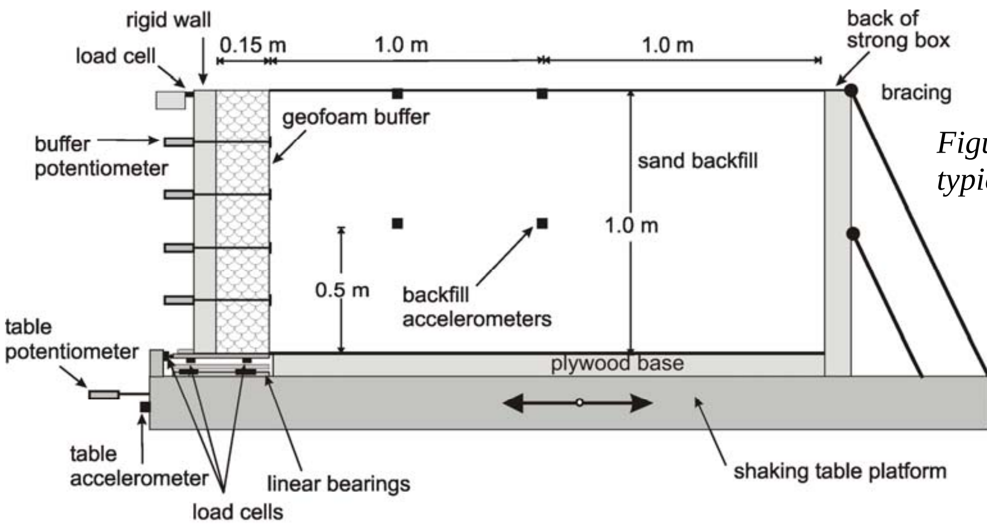


Figure 1. Cross-section of typical physical test

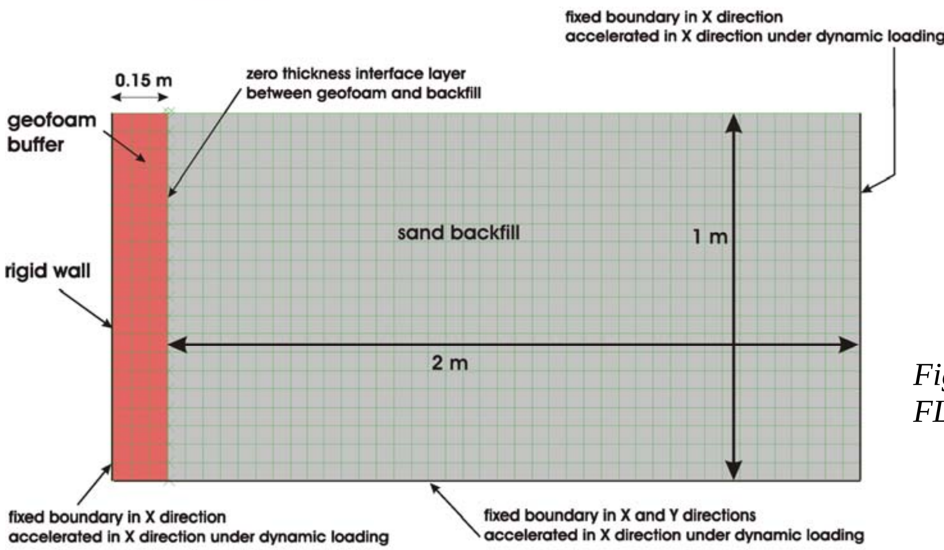


Figure 2. FLAC numerical grid

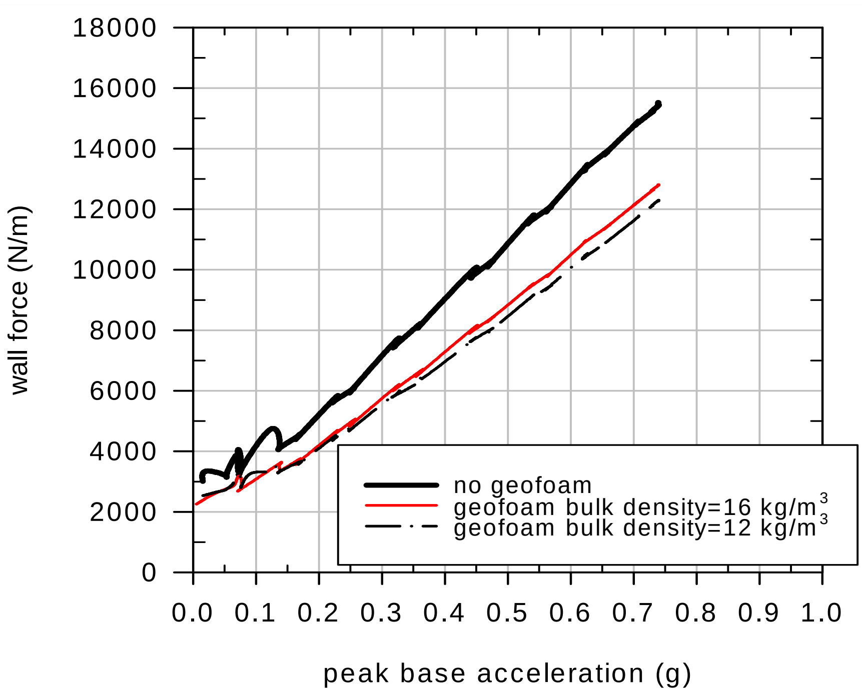


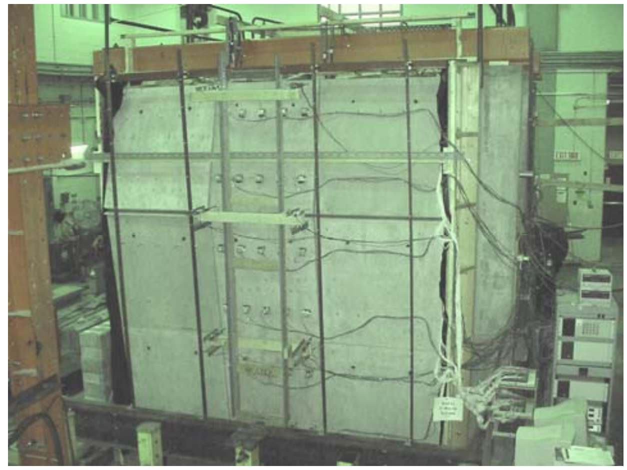
Figure 3. Comparison of predicted wall force versus peak base acceleration from numerical simulations

Limit States Design of Reinforced Soil Walls

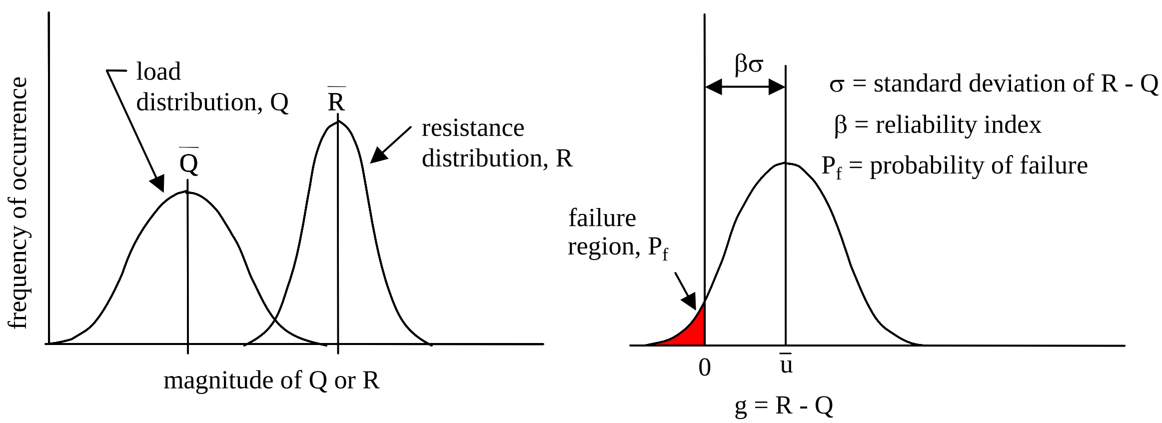
By Richard J. Bathurst and Bing Huang

Future editions of AASHTO design codes are committed to a fully limit states design (LSD) approach for all structures, including reinforced soil walls. Where reinforced soil walls are considered in current codes, they are based on LSD calibration to allowable stress design (ASD) practice, which is recognized as an interim approach.

At the GeoEngineering Centre, work is underway to calibrate metallic and geosynthetic reinforced soil wall design methods within an LRFD framework. A large database of statistical parameters has been collected using field-monitored structures and a suite of full-scale walls constructed in the RMC Full-scale Retaining Wall Test Facility.



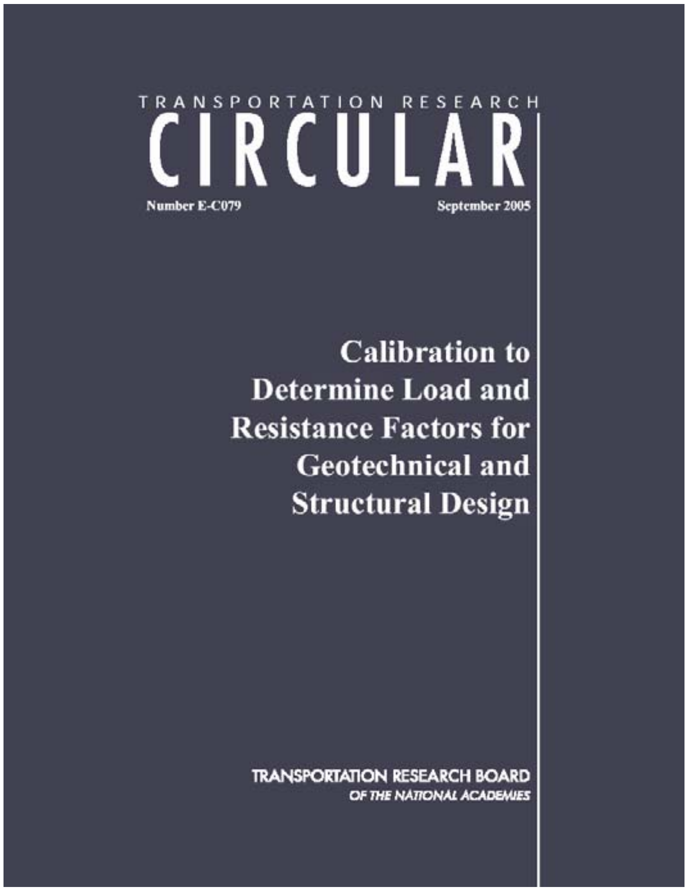
Example of RMC concrete panel wall at an ultimate limit state as a result of uniform surcharge loading



a) frequency distributions for random values of load and resistance terms *b) probability of failure*

Figure 1. Probability of failure in reliability-based design

The general approach adopted for calibration is reliability-based design together with "bias" values computed from a database of measurements from laboratory pullout tests and loads recorded from instrumented structures. Bias values are defined as the ratio of measured to predicted values and these values are implemented within closed-form solutions and using Monte Carlo simulation to calculate resistance and load factors.



A Transportation Research Circular has been recently prepared by Professor Bathurst in co-operation with Tony Allen (Washington State Department of Transportation) and Professor Andy Nowak (University of Nebraska). This guidance document for LSD calibration of geotechnical and structural design of transportation-related structures is available at "www.TRB.org".

The document attempts to demystify LSD calibration so that geotechnical engineers can gain confidence in the LSD approach to design of geotechnical structures, and even can carry out LSD calibration themselves.

Figure 2. Transportation Research Circular

Measuring the In-soil Behaviour of Geosynthetic Reinforcement

By Richard J. Bathurst, Mahmoud Elbanna and Andy Take

Current design methods for reinforced soil structures use properties of the reinforcement established from in-air tensile testing. Careful monitoring of geotextiles and some drawn polyolefin geogrid products has shown that they contract laterally during loading in air. This has led to the hypothesis that the stiffness of these materials when confined in soil may be greater than that deduced from conventional constant load tests or constant-rate-of strain tests. A practical consequence of this phenomenon is that the loads in reinforced soil walls may be higher than originally assumed.

To investigate this hypothesis a special apparatus has been constructed at RMC that allows the strains in the reinforcement to be measured while confined in soil. The measurement of strains is carried out using advanced algorithms for target tracking from high-resolution photographs.

The colour photograph shows a geogrid specimen located at the bottom of the test apparatus below a layer of sand. The transparent bottom boundary allows photographs to be taken of the specimen while under vertical confining pressure and loaded in tension from one or both ends of the test apparatus. The load-strain response of the specimen under soil confinement can be deduced from boundary loads and measured strains.

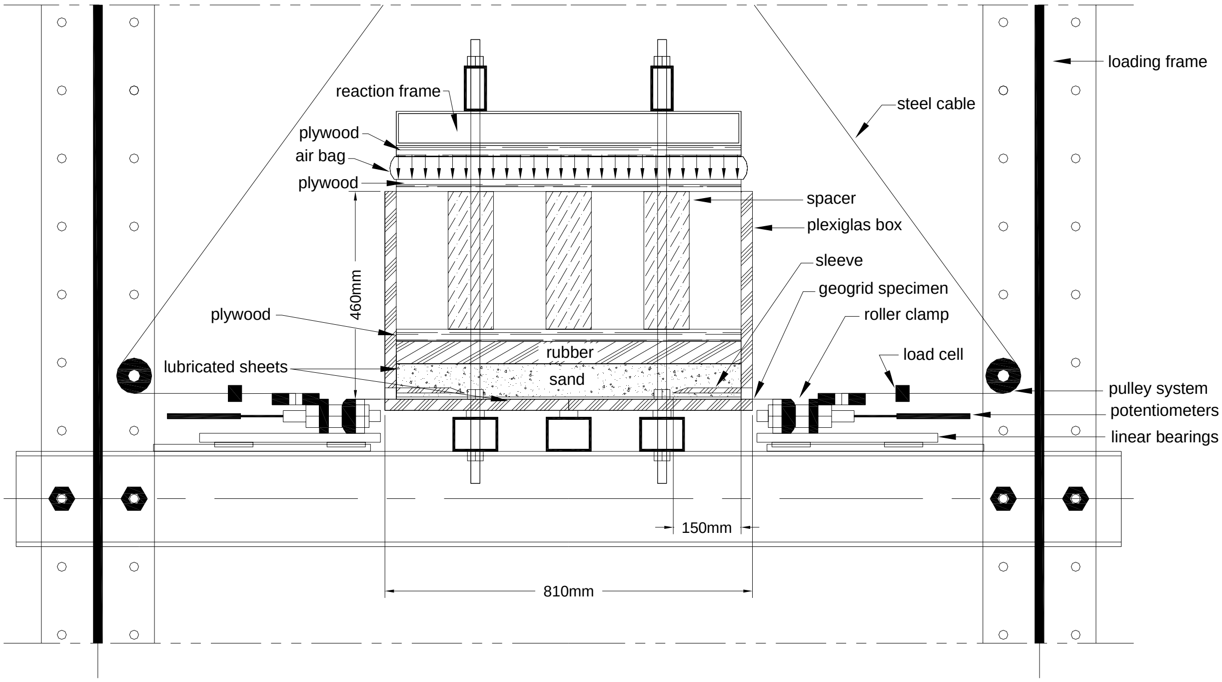


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Figure 1. Cross-section view of test apparatus

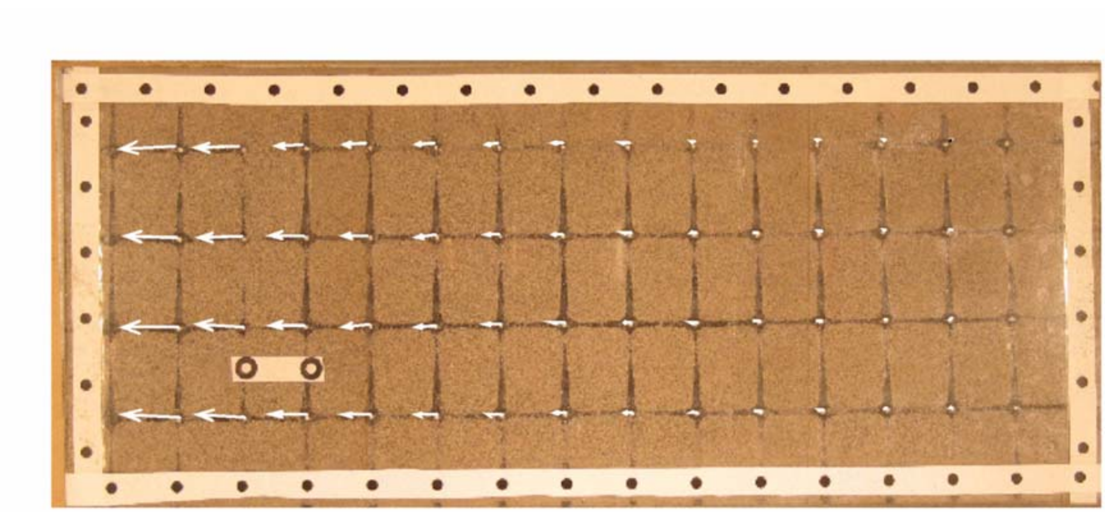


Figure 2. Photograph of confined geogrid reinforcement specimen viewed through the transparent bottom of the in-soil testing apparatus and displacement vectors measured at junction.

Potential for Spontaneous CO_2 Sequestration at EKATI Diamond Mine

By Heather Jamieson

An industrial process that spontaneously sequesters atmospheric CO_2 seems to be too good to be true. However, geochemical investigations by Queen's researchers suggest this may be happening at EKATI Diamond mine, NWT, Canada. Their field studies, modeling and experimental evidence indicates that crushing and washing of kimberlite ore results in rapid dissolution of magnesium silicates and precipitation of silica and carbonate minerals. This reaction is similar to the mineral carbonation reaction that has been proposed by as a method of fixing CO_2 in a stable solid form.

Claudine Lee recently completed an MSc under the supervision of Dr. Heather Jamieson exploring the potential for CO_2 sequestration at EKATI.. The research was funded by BHPBilliton, operators of the mine. EKATI is one of two (soon to be three) diamond mines operating in the NWT and contributes to Canada's third place position in global diamond production by value.

A previous graduate student of Jamieson's, Andrew Rollo, had noted that the composition of the water discharged from the processing plant, where the diamonds are removed from kimberlite ore, was distinctive from the intake water, presumably as a result of water-rock interaction since no chemicals are added in the plant. Claudine sampled intake and discharge waters, as well as processed kimberlite fines, during several field visits to the mine. She used the water analyses to calculate the likely mineral dissolution and precipitation reactions occurring in the plant and then conducted experiments that reproduced that change in water chemistry observed in the processing plant, notably a rapid increase in pH, alkalinity and the products of mineral dissolution.

EKATI Diamond Mine is located 300 km NE of Yellowknife (Image courtesy BHPBilliton Ltd)

The only geochemical reasonable explanation for the change in water composition was the dissolution of the magnesium silicates (serpentine and olivine) that make up most of the kimberlite, and the precipitation of silica and a carbonate mineral such as calcite or magnesite. This reaction can only proceed if CO_2 from the atmosphere is simultaneously dissolved in the water. The amount of CO_2 that may be sequestered spontaneously in the EKATI kimberlite processing plant is modest, partly due to the fact that the kimberlite ore spends only one hour in the plant. Claudine's results are particularly significant in showing that no additional input of energy is required to dissolve magnesium silicates, the first step in mineral carbonation.

The connection between EKATI diamond mine and researchers from the GeoEngineering Centre continues with the graduate project of Kathy Kalenchuk on the structural influences of dilution caused by host rock instability during caving of the kimberlite pipe. This thesis is co-supervised by Mark Diederichs and Steve MacKinnon.

H. Jamieson & C. Lee at EKATI mine April 2004

Underground at Ekati: Geological controls on dilution and flow control

By Kathy Kalenchuk, Mark Diederichs and Steve McKinnon

Ekati Diamond Mine is located approximately 300 km northeast of Yellowknife. Surface mining has been on going at Ekati since 1998; now as the open pits approach their economical limits the mining method is changing to the underground technique of sublevel caving. The Ekati project is receiving special attention as a test case for future widespread development of similar deposits.

Ekati Diamond Mine is located approximately 300 km northeast of Yellowknife. Surface mining has been on going at Ekati since 1998. As the open pits reach their economical limits the mining method must be transitioned to underground operations. To date Koala North and Panda are the only kimberlite pipes with underground operations, using an open benching mining method it is the first underground diamond mine in North America.

Koala Pipe is the next kimberlite scheduled to start underground production, using the sublevel caving mining method. Sublevel caving has never been applied in Canadian diamond mines, as such the method must be thoroughly investigated to minimize risk to mine productivity and economics, the focus of this study is to contribute to minimizing risk by improving knowledge of anticipated dilution. The design and operation of this underground mine will serve as an important test for the future production of other diamondiferous kimberlites in Canada's North.

Sub level caving is a top down mining method that has the potential for high production at low cost. This method can reach production with relatively low capital requirements since ore extraction starts relatively early in the development cycle. The method involves the creation of a network of offset drilling drifts throughout the volume of the pipe.

The ore is blasted from and between these drifts to create a fractured ore mass that can then be drawn from extraction levels at the bottom of the pipe block. The efficiency and economics of the final drawing of the easily fragmented ore can be significantly impacted by the release of larger blocks of waste rock from the surrounding walls of the pipe. Such blocks would cause dilution and would impede the flow of kimberlite ore.

This work by MSc. student Kathy Kalenchuk with co-supervision from Mark Diederichs in Geological Engineering and Steve McKinnon in Mining Engineering, is aimed at quantifying the dilution potential based on structural geology inputs. The size and shape distributions of dilution blocks can be predicted, this knowledge will lead to an assessment of how predicted dilution may migrate through the muck flow and drawing process. To achieve these goals, Kathy is integrating field mapping and structural assessment with 3DEC (discrete block) simulations, geometrical statistics and PFC (particle flow) modelling.

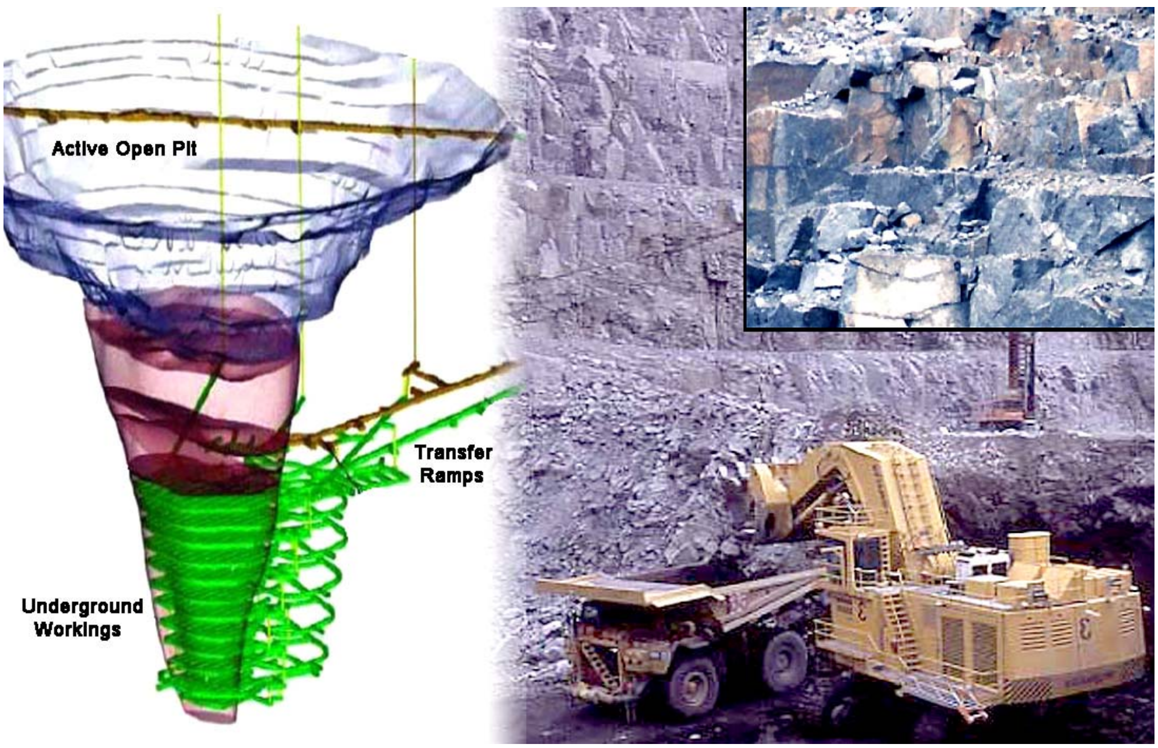


Figure 1: Open pit and future underground mining at Ekati. Rockmass in the pit at right will serve as a predictor for rock behaviour at depth.

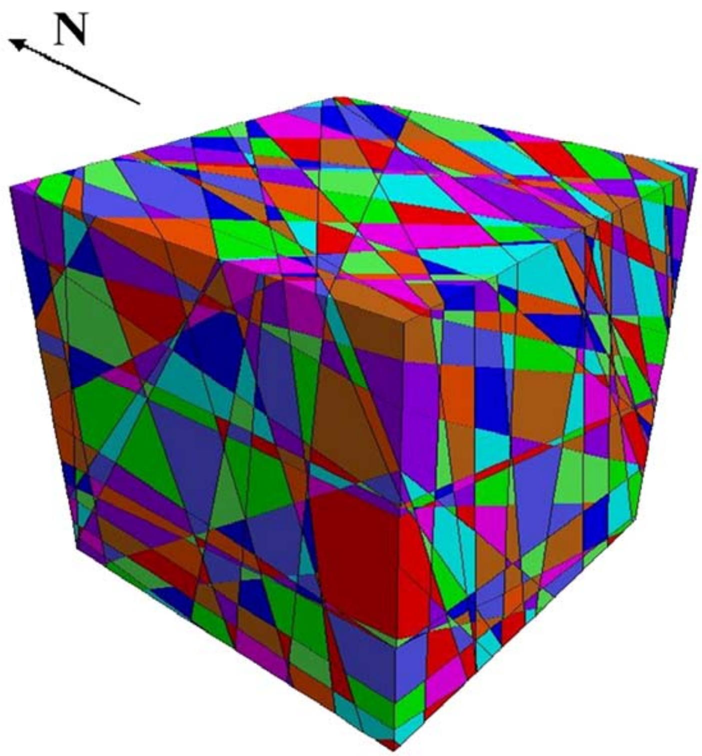


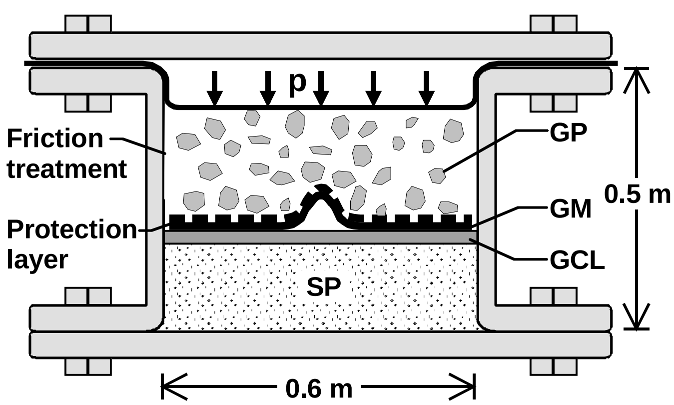
Figure 2: Reconstructed block geometry model used to extract geometrical statistics related to block size and shape distribution in the host rock.

Ensuring the Long-term Performance of Geosynthetic Liners

By Richard Brachman

Despite tangible results from efforts to reduce, reuse and recycle waste, our growing communities will continue to require new and larger landfills for the safe disposal of municipal and industrial solid waste for the foreseeable future. To contribute to the sustainable development of our urban centres, Canada needs waste containment sites that provide long-term environmental protection in order to prevent future groundwater contamination problems. Geosynthetic liners comprised of a geomembrane (1.5-2 mm thick high-density polyethylene plastic sheet) overlying a geosynthetic clay liner (10 mm thick layer of low permeability bentonite typically encased between two geotextiles) can be used to greatly enhance the environmental protection of a properly designed landfill barrier system. However, there is some uncertainty as to how long these geosynthetic liners will last. To this end, Drs Kerry Rowe and Richard Brachman were recently awarded $578,000 from Natural Sciences and Engineering Research Council of Canada to conduct research aimed at developing an understanding of the long-term performance of geosynthetics used in landfill barriers and to develop guidelines to enhance their long-term performance.

The research will involve accelerating the ageing process in the laboratory using elevated temperatures and then monitoring the changes in key liner properties with time. The effects of ageing on liner performance will be examined under simulated field conditions that include: a full liner system (so that the interaction between the different components can be considered), exposure of the liner to contaminated water (simulated landfill leachate), and imposition of loading like that caused by the overlying waste in a landfill.



Experimental apparatus to simulate the physical response of composite geosynthetic liners (GP: gravel, GM: geomembrane, GCL: geosynthetic clay liner, SP: sand, p: applied pressure).

Geosynthetics liner longevity research team (from left to right): Simon Dickinson, Kerry Rowe, Richard Brachman, Zahirul Islam, Ali Sabir, Khaled Abdelatty and Santosh Rimal.

This project presently involves six Doctoral students: Zahirul Islam, Simon Dickinson, Santosh Rimal, Rebecca McWatters, Ali Sabir and Khaled Abdelatty. This project also involves collaboration with Dr. Grace Hsaun from Drexel University (USA); government partners from Ontario's Ministry of the Environment; geosynthetic manufacturers Solmax International and Terrafix Geosynthetics; consulting engineering firms AMEC Earth and Environmental, Gartner Lee and Golder Associates; and commercial testing laboratory Sageos.

Ground movements caused by pipe bursting

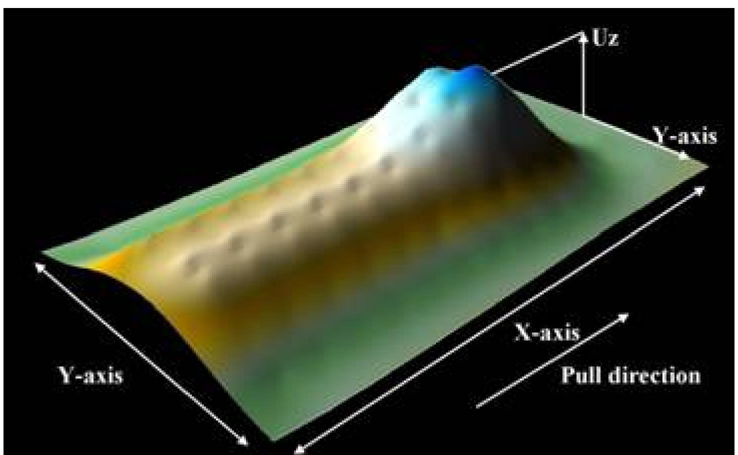
by Ian Moore and Richard Brachman.

Pipes composed of brittle materials can be replaced using static pipe bursting. This involves pulling a conical bursting head through the existing pipe, where a blade on the burst head fractures the existing pipe, and the remaining fragments are pushed out into the surrounding ground. A new HDPE or other pipe attached to the end of the burst head is then pulled into place through the expanded cavity. While this 'trenchless technology' has been available for two decades, only empirical guidance has been available regarding:

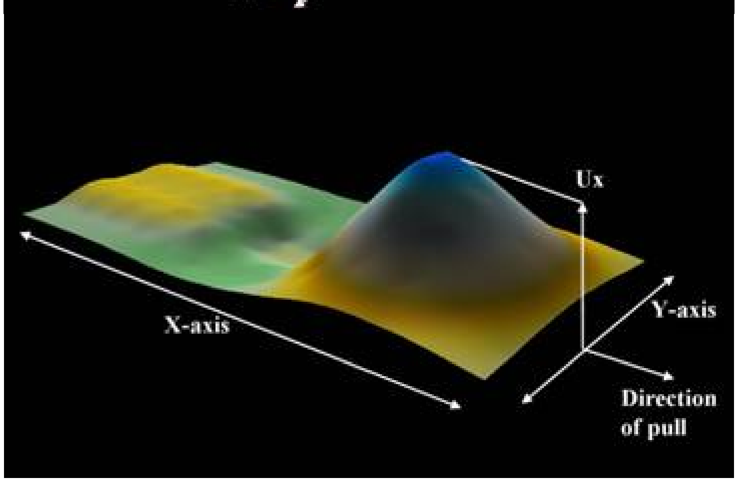
1. disturbance to adjacent or overlying infrastructure associated with the cavity expansion;
2. the magnitude of pulling forces needed.

Brian Lapos (MSc, 2004) conducted pipe bursting simulations in the laboratory, obtaining unique measurements of vertical movements at the ground surface, as well as horizontal movements in the direction of the burst and laterally. These measurements have been used to evaluate the performance of new finite element procedures to calculate ground movement and pulling forces developed by Viji Fernando (MESc, 2002) and Michael Nkemitag (PhD in progress). The calibrated finite element models are being used to develop new design procedures.

Burst head and set-up of burst head and replacement pipe prior to conducting a bursting experiment (Lapos, 2004).



Experimental measurements of uplift at ground surface, Lapos (2004)



Measurements of forward movement at the ground surface, Lapos (2004).

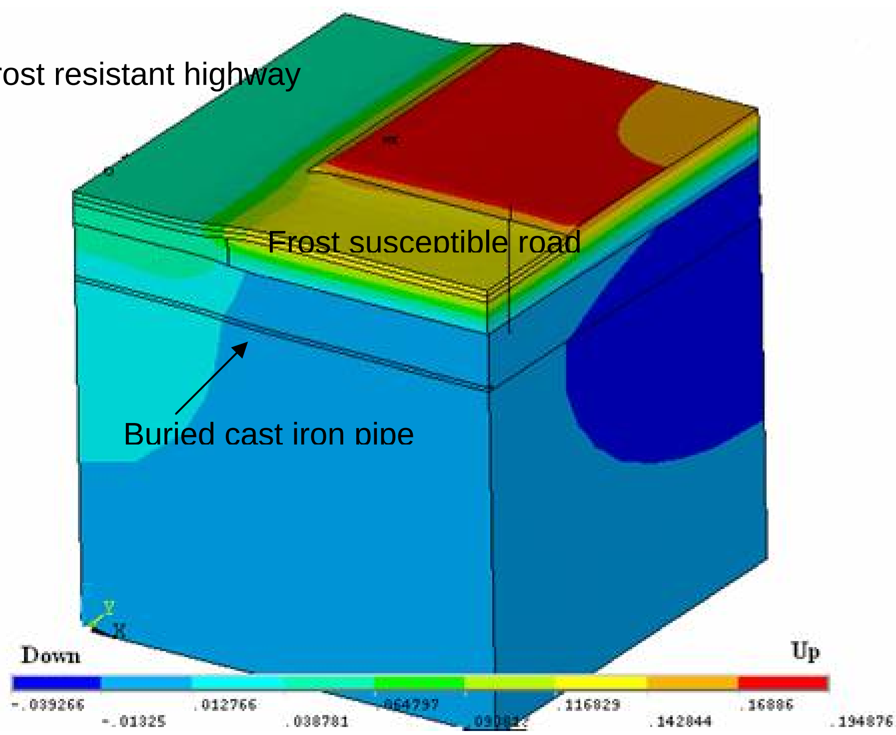
Fracture and rehabilitation of buried cast iron water pipes

By Ian Moore, Andy Take, and Amir Fam

Typical costs of water pipe replacement of $50/annum per resident in cities like Hamilton imply investments exceeding $1B each year across Canada. These huge expenditures are prioritized by municipal engineers based on break rate data, and much needs to be learned regarding the causes and potential prevention of fractures. About 80% of grey cast iron pipe failures in Ontario are by ring fracture during or immediately following ground freezing. NSERC Discovery grant funding is being used to develop rational explanations for these failures. While conventional wisdom indicates that pipes placed below the frost line are immune to frost action, cities like Ottawa have progressively continue to increase depths of burial since pipes continue to fracture. Sue Trickey (MSc, 2005) used three dimensional finite element procedures to explore the bending moments that develop in pipes where they pass under transitions between frost susceptible and non-frost susceptible pavement structures. These analyses demonstrate that typical thermal conditions can produce ring fractures as a result of differential ground movements, even when pipes lie below the frost-line. The analysis is being used to provide guidance regarding the effect of material and geometrical conditions like the stiffness of the backfill soil and the burial depth. New doctoral student Masoumeh Saiyar has commenced work with Ian Moore and Andy Take to obtain physical data on buried pipes responding to frost action, including laboratory and field measurements. This will permit calibration of the numerical models, and development of design guidance.

A novel cast iron pipe repair system developed by Sanexen of Montréal is being used in municipalities in Ontario and elsewhere. Use of this cast in place liner system is facilitated because the Sanexen technology includes the ability to reopen service connections from inside the liner using a robotic system (avoiding the need for excavations at each connection). A project by Erez Allouche (Louisiana Tech) and Ian Moore for Hamilton evaluated the liner system and identified a number of potential ultimate limit states that require consideration. NSERC Strategic Research Grant funding to Ian Moore, Amir Fam (Civil Engineering, Queen's), and Hanping Hong (Civil Engineering, UWO) is permitting work by graduate students Nancy Ampiah, Michael Brown, Reza Molaee and R.D. Villarreal to establish the critical performance limits for cast iron pipe repair using liners, and to develop a decision support system for use by Municipal research partner Hamilton City and other municipalities.

Corroded water pipe, Hamilton 2003. *Liner repair, Hamilton 2003.*



Three dimensional finite element analysis of frost induced ground movements and the bending moments induced in buried cast iron water pipes, Trickey (2005).

Richard Brachman and Mark Diederichs Receive the Premier's Research Excellence Award

By Ian Moore

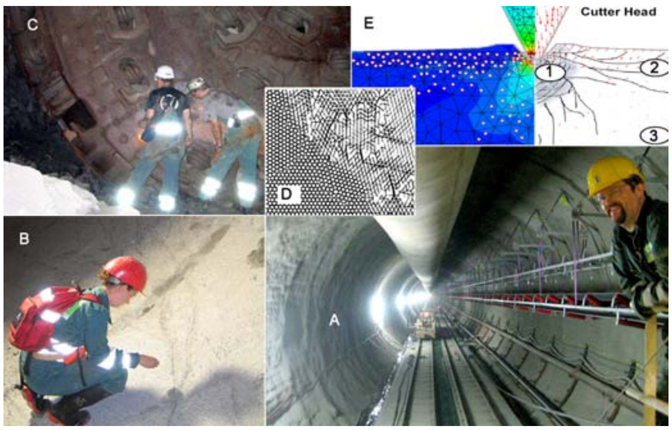
Queen's announced in March 2005 that Centre members Richard Brachman and Mark Diederichs were to receive the Premier's Research Excellence Award. The awards were created in 1998 to help Ontario's world-class researchers attract talented people to their research teams and to encourage innovation among the province's brightest young researchers at universities, hospitals and research institutes. PREA winners receive up to $100,000 from the Ontario government and $50,000 from their university, to further their research. Making the announcement Vice-Principal (Research) Kerry Rowe said "Congratulations to our most recent PREA recipients. These prestigious awards recognize the exceptional caliber of their work, as well as their potential to make a real difference in the lives of Canadians".

Dr. Richard Brachman was selected as a PREA recipient for his project titled "Resolving two critical buried municipal infrastructure issues".

Dr. Brachman (right) with PhD students Simon Gudina (left) and Ryan Krushelnitzky (centre).

Ontario's aging and growing cities need viable economic techniques to repair deteriorated buried structures and durable landfill barriers to prevent contamination of the environment. In response to these challenges, Dr. Brachman and his graduate students will quantify the structural capacity of deteriorated manholes repaired with polymer liners, and assess the physical response of drainage pipes in landfills. PREA is intended to help gifted researchers attract talented graduate students, post-doctoral fellows or research associates to their research teams and is administered by the Science and Technology Division, Ministry of Economic Development and Trade of the Government of Ontario. Dr. Brachman was also awarded Queen's Chancellor's Research Award. This is the largest single internal research award at Queen's to recognize excellence and innovation among researchers appointed to their first full-time position within the past eight years.

Dr. Mark Diederichs was awarded the PREA for his project: "Scaling of Applied Damage Mechanics and Yield Models for Brittle Rockmasses". Conventional failure criteria for earth materials are inadequate for brittle rock near excavations. Building on recent theoretical damage models, this project is aimed at investigating the adaptability of these new models to the prediction of fracture and yield processes at three applications at different scales of engineering work and at different scales of material (geological) heterogeneity. The first relates damage theory at a small scale to the efficiency of hard rock tunnel boring machines or raise boring cutter heads. The second relates complex damage processes to rock stability near a tunnel face. The third adapts these models to predict progression of fracture and caving in a large-scale mining operation. All of these components are aimed at improving performance, increasing safety and reducing economic risk due to geological variability in capital intensive infrastructure and mining projects.



A) Dr. Diederichs in the Gotthard Tunnel;
B) PhD student Marlene Villeneuve evaluating tunnel wall and
C) TBM cutter condition;
D) Micromechanical model and
E) FEM model for cutter mechanics.

OTHER AWARDS

Richard Bathurst and **Kianoosh Hatami** received the Casmir Gzowski medal of the Canadian Society for Civil Engineering for their paper in the Can. Geotechnical Journal.

Richard Brachman was recently awarded a Queen's Chancellor's Award.

PhD Student **Karina Lange** received an award from the North American Geosynthetics Society for the Best student paper and presentation at the Las Vegas Conference in 2005.

The Province of Ontario honoured the successful team of GeoEngineering Centre members (**Kerry Rowe, Richard Bathurst, Richard Brachman**, and **Ian Moore**) in recognition of their $1.6M research infrastructure project "Ensuring Performance of Geosynthetics under Extreme Environmental Conditions".

Kerry Rowe received the Outstanding Contributions Medal from the International Association for Computer Methods and Advances in Geomechanics "for seminal research contributions in geomechanics … adopted for basic research and practical applications".

Students **Melissa Chappel**, **Steven Gaines**, and **Tanya Neumeyer** of the Queen's Geological Engineering B.App.Sc. program were overall winners of the CGS Undergraduate Report Awards (Group Submission).

RANKINE LECTURE, Imperial College, March 2005

By Ian Moore

I was delighted to be in attendance at Imperial College in March when Kerry Rowe, accompanied by Kathy and their children Katrina, Kieron and Kendall, was honoured by the British Geotechnical Association and afforded the opportunity to deliver the 45th Rankine Lecture[1]. Kerry's presentation titled "Long-Term Performance of Contaminant Barrier Systems" covered the broad range of his contributions explaining the mechanisms of behaviour of these barrier systems, including recent advances in the understanding of advective transport associated with perforations and wrinkles in Geomembranes, operating temperatures for these barriers and the impact of temperature on Geomembrane longevity, as well as the mechanisms of biological clogging, diffusion of organic and inorganic compounds, and the resulting design estimates of long term performance.

In his presentations, he has been quick to acknowledge the importance of the contributions to his work of his more than 50 graduate research students and his colleagues and collaborators at Queen's and internationally.

Kerry has subsequently completed the written version of the lecture (see publications list) and has presented the lecture in Turin, Calgary, at the Canadian Geotechnical Conference in Saskatoon, and in Sydney, Newcastle, Brisbane, Gold Coast, Melbourne, and Perth in Australia, as well as Hong Kong and Johannesburg. Kerry also presented his Rankine lecture as part of our *Geo*Engineering Seminar Series at Queen's on November 2.

[1] *"William Rankine, for whom the lecture is named, was a Scottish-born, 19th-century civil engineer whose scientific findings form the foundation of modern thermodynamics and soil mechanics. He is also renowned internationally for pioneering engineering education. Rankine lecturers are chosen on the basis of their international standing and reputation, their technical expertise and contribution to geotechnical engineering, their ability to deliver an outstanding lecture, and to produce a published paper that would serve as a landmark to industry". (from the press release by BGA director Tony Bracegirdle).*

RECENT GRADUATES

The following GeoEngineers associated with the Centre have recently completed their training, and have moved on to the next phase of their career.

- **Dan Babcock,** MSc (An Evaluation Of Model Parameters For Clogging Of Coarse Drainage Material And Tire Shreds In Landfill LCS, supervisor Kerry Rowe), Project Engineer, Golder Associates, London
- **Cathy Banton**, MSc (Numerical Modelling of Shotcrete Failure Mechanisms, supervisors: Mark Diederichs, Jean Hutchinson)
- **Paul Hurst** MSc (Performance of GCLs exposed to Jet fuel A-1 between +20 and -20ºC, supervisor Kerry Rowe), Project Engineer, Golder Associates, Ottawa
- **Ho-young Jeong**, PhD (Analysis and Design of Loadout Tunnels Under Ore Stockpiles, supervisor: Ian Moore), Postdoctoral position, Queen's University
- **Heather Lindsay,** MSc (Permeation Of Hydrocarbons Through HDPE And F-HDPE Geomembranes, supervisor Kerry Rowe), Project Engineer AMEC, Toronto
- **R. Nelson**, MSc (supervisor, Richard Bathurst) DND Engineering Support Unit, Moncton, NS
- **Jon Southen** PhD (Thermally Driven Moisture Movement Within And Beneath Geosynthetic Clay Liners, supervisor Kerry Rowe), Assistant Professor UWO
- **Susan Trickey**, MSc (Three dimensional finite element modeling of buried pipes including frost action, supervisor: Ian Moore), Golder Associates, Ottawa

Kianoosh Hatami, an Associate Research Director of the GeoEngineering Centre and Postdoctoral Research Fellow (supervisor Richard Bathurst) has been appointed as an Assistant Professor at the University of Oklahoma.

Toshifumi Mukunoki, an Associate Research Director of the GeoEngineering Centre and Postdoctoral Research Fellow (supervisor Kerry Rowe) has been appointed as an Associate Professor at Kumamoto University, Japan.

INDUSTRIAL SPONSORS, 2005

- BHP Billiton
- City of Hamilton, ON
- CRESTech
- Department of National Defence
- Florida Department of Transportation
- The Gillette Company, Needham, MA
- Golder Associates, Burnaby BC
- Infrastructure Canada
- Ipex Inc., Mississauga, ON
- James Hardie Building Products Inc, Florida
- Ministry of Environment
- North Warning System Office, Department of National Defence, Canada
- Solmax International
- Terrafix Geosynthetics Inc., Toronto, ON

RECENT PUBLICATIONS

GeoTechnical

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Archibald, J.F, Dirige, A.P. and Katsabanis, P.T., (2005). Update on WSIB Research Into Testing of New Spray-On Liner and Composite Superliner, Area Supports. Mining Health and Safety Conference 2005. Mines and Aggregates Health and Safety Association of Ontario, Sudbury, Ontario, April 12-14, 2005. 23 pages (CD-ROM publication).

Archibald, J.F. and Dirige, A.P., (2005). Spray-On Lining Innovation for Support in Burst-Prone Mine Environments and Tunnel Coatings in Civil Engineering Use. U.S. Rock Mechanics Symposium, Fairbanks, Alaska, June, 2005.

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