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Volume 31 • Number 2 • June 2013

GEOTECHNICAL news

Field Monitoring Challenges, Unforeseen Movements

Thesis Abstracts 2013

innovation

in MEMS Digital Inclinometer Systems

DIGITAL MEMS INCLINOMETER SYSTEM

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For measuring any lateral movement down in the earth, via inclinometer casing, the Digital MEMS Inclinometer System from RST Instruments Ltd. was the first, and is still the best, Digital MEMS Inclinometer System available.

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OTHER INCLINOMETERS VS. RST

Other Inclinometers → ← **RST Inclinometer**

Interference

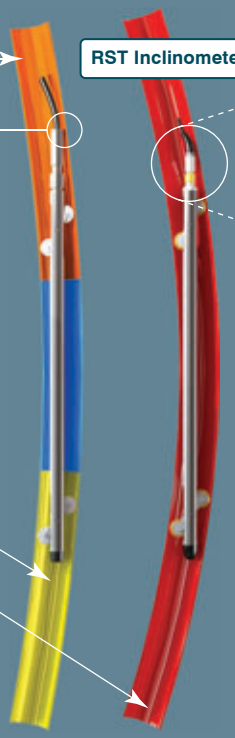
Interference at connector is visibly inherent in other inclinometers (left) while RST's Digital MEMS Inclinometer (right) can clearly traverse a smaller radius bend (1.93 m) than all other inclinometers.

Minimum Negotiable Casing Radius

Other Inclinometers:
3.12 m

RST Inclinometer:
1.93 m

0.5 m wheelbase probes shown in 70 mm OD inclinometer casing.



RST's newly developed connector is by far the industry leader for the least amount of connector interference.

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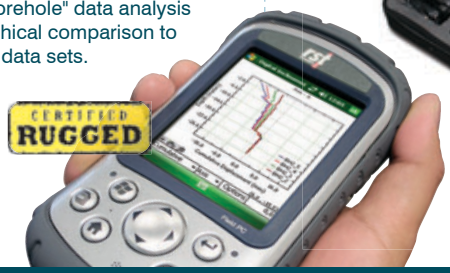

SYSTEM INCLUDES:

MEMS Digital Inclinometer probe, cable system, reel with battery power, and an Ultra-Rugged Field PC that functions as a wireless readout, analysis, and data storage device. Includes all accessories, as shown at left. Please contact the RST sales team for complete details.

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BiTech Publishers Ltd.
103 - 11951 Hammersmith Way
Richmond, British Columbia
Canada V7A 5H9
tel 604-277-4250 • fax 604-277-8125
email *gn@geotechnicalnews.com*
web *www.geotechnicalnews.com*

GEOTECHNICAL NEWS is published quarterly.

Paper subscription rates:

- within North America: $51.00 CDN per year
- overseas: $85.00 US per year through BiTech Publishers Ltd.

Electronic version:
GEOTECHNICAL NEWS is also available in electronic version. For details,visit
www.geotechnicalnews.com

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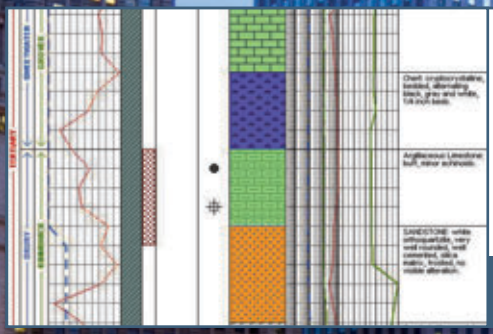

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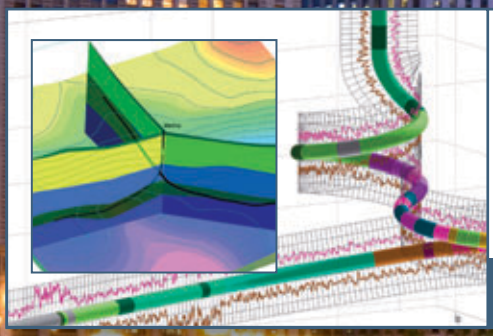

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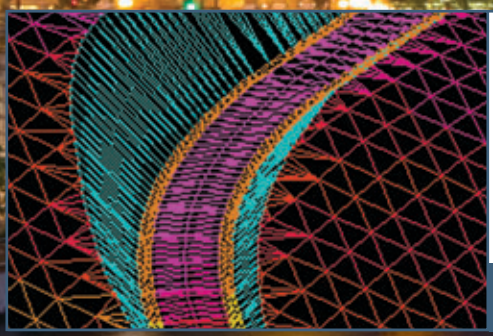

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CONTENTS

Cover Widening of a roadway adjacent to a wetland area utilizing a permanent retaining wall showing the sheet pile wall, anchor piles and one of the attached inclinometers as part of the monitoring plan. *(Photo by Tina Curley at Monir Precision Monitoring Inc.)*

$5.5 Billion Panama Canal Project Relied on Bentley Geotechnical Software

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Panama Canal Widening Project

When the cost of dredging 20 million cubic meters is calculated on type and volume of materials – and on whether it is above or below sea level – you need accuracy you can rely on. The $5.5 billion Panama Canal widening project consists of more than 10 different types of material and methods of removal. Jan De Nul used Bentley's geotechnical software to store and analyze geological data and used our road design software to build 3D models of the material profiles that were also used for machine control.

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Message from the President

Richard J. Bathurst, President of Canadian Geotechnical Society

By the time you read this message, the new executive for 2013-14 will have been in place for six months. The CGS executive held its first biannual meeting on April 27 in Toronto. What has certainly made an impression on me is the large amount of activity required to keep our Society running smoothly.

I am pleased to be able to announce the names of several new chairs for Divisions, Sections and Committees, whose appointments became effective in 2012 and 2013. Most chairs serve for three years and the entire roster of chair appointments are purposely staggered over three years, to ensure that the Board of Directors always has a mix of both new and experienced individuals.

The recently appointed new Division chair for Engineering Geology is **Doug Stead**, replacing Davide Elmo. The new Section Directors are **Jason Pellett** (Vancouver), **Suzanne Powell** (Vancouver Island), **Eric Mohlmann** (Prince George); **Sumi Siddiqua** (Interior British Columbia), **Mamadou Fall** (Eastern and Northern Ontario), **Eltayeb Mohamedelhassan** (Thunder Bay), **Mrinmoy Kanungo** (London); **Jean Côté** (Eastern Quebec), and **Janet Williams** (Newfoundland). I am also delighted to report that there is an initiative to form a New Brunswick chapter, led by **Hany El Naggar** in Fredericton. The new chairs of the CGS Standing Committees are **Michael Porter** (Landslides) and **Roger Skirrow** (Transportation Geotechnique). Finally I am pleased to announce that **Don Lewycky** is the new Editor of the CGS News section in Geotechnical News, replacing Phil

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Bruch who held the position for two full terms (6 years). I wish to thank all of these individuals for agreeing to donate their time and experience to these important positions. CGS members are also reminded that membership in section groups is strongly encouraged and most committees are open to all CGS members.

The CGS Cross Canada Lecture Tour brings one national and one international expert to selected sections across the country each year. **Mike Jefferies** was our fall 2012 speaker and offered our members the choice of three different talks; The State Parameter – it is Older Than You Think and Widely Applicable, Flaws in the NCEER Liquefaction Assessment Method and How to Fix Them, and Looking Towards Beaufort Sea Development – Experience of Design, Regulation and Reality with the Molikpaq 1984-9.

Robert (Bob) Cameron from Syncrude Canada Limited was our spring 2013 speaker and gave talks on either Case Studies in Soil Parameter Selections for Clay Foundations or Compaction and Design Tips for Constructing Fills at Rates up to 25 million m^3/year.

The fall 2013 CCLT speaker will be **Dr. Ed Kavazajian** from Arizona State University. He will be offering a slate of six possible talks from which to choose. Contact your local section to see if he has been scheduled to speak to your group.

Several CGS members were honoured by the Engineering Institute of Canada (EIC) at its annual banquet in May in Montreal: Peter K. Kaiser received the Julian C. Smith Medal and Ian D. Moore received the John B. Stirling Medal. Iain G. Bruce, Denis LeBoeuf and Robert J. Fannin were all made Fellows of the EIC. Congratulations to them all.

Preparation for the upcoming **66th Annual CGS Conference,** to be held in Montreal on September 29 to October 3, is well underway. Accepted papers are now being processed by the conference organizers.

Immediately following this conference will be the **4th Canadian Young Geotechnical Engineers and Geoscientists Conference** (cYGEGC). This is a triennial CGS event that creates a relaxed environment where young (less than 35 years of age) members of the geoengineering and geoscience communities can share technical knowledge, network and exchange career experiences. The venue for the conference is Mount Tremblant and the dates are October 3 to 6. The chair of this conference is **Ariane Locat** who, with her committee of talented young people, has done a truly outstanding job getting this conference launched. The conference has been assisted by sponsorships from industry and guidance from the CGS Education Committee. The Cold Engineering and Rock Mechanics Divisions are jointly sponsoring one student to attend the cYGEGC.

Finally, the Education Committee of the CGS and the Canadian Foundation for Geotechnique have jointly established an award to give two CGS members under the age of 35, the opportunity to attend the **5th International Young Geotechnical Engineers Conference** in Paris, France in the fall of 2013. Many outstanding nominations were received and ultimately **Nicholas Beier** (University of Alberta) and **Vincent Goreham** (Dalhousie University) were selected as the award winners.

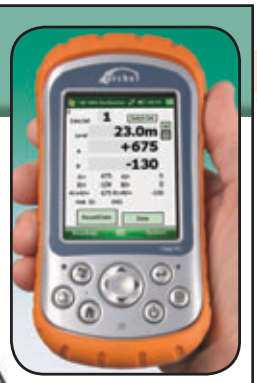
I hope to see you all at **GeoMontreal 2013**.

Provided by Richard Bathurst – President

Message du président

Lorsque vous lirez ce message, le nouveau Comité exécutif de la SCG

GK-604D Digital Inclinometer System



The Geokon GK-604D Digital Inclinometer System is our latest advancement in inclinometer technology. Fully equipped with a MEMS digital inclinometer probe, reel-mounted cable, and an all-weather Field PC, the GK-604D system is designed to measure lateral movements in and around:

- Slurry Walls
- Piles
- Landfills
- Tunnels
- Landslides and Unstable Slopes
- Dam Embankments
- Sheet Piling
- Caissons

NEW

The rugged hand-held Field PC communicates via Bluetooth® radio with an interface located inside the inclinometer cable reel. For greater accuracy the MEMS analog output is digitised inside the probe. The Field PC will automatically recognise the ID of the connected probe and apply the proper calibration factor. Survey readings are stored in the Field PC for transfer to a host computer for further data analysis.

www.geokon.com/digital-inclinometer-system

High Capacity Load Cell Calibration Press

Today, load cells with higher capacities are becoming more commonly used in geotechnical applications. Consequently, there is a need for reasonably-priced calibration reports with accuracies that are traceable to the NIST standards. Geokon, has installed a custom-built press, manufactured by Grimco of New Jersey, which is capable of performing calibrations of up to 1,200 tons.

If you have a need for the calibration of high capacity load cells and/or hydraulic jacks, **please contact Geokon for more information.**

UP TO 1,200 TONS

pour l'exercice 2013-2014 aura été en fonction depuis six mois et aura tenu sa première réunion semestrielle le 27 avril à Toronto. J'avoue avoir été impressionné par l'ampleur du travail à réaliser pour assurer le bon fonctionnement de notre société.

J'ai le plaisir d'annoncer les noms des nouveaux présidents ou directeurs de divisions, de sections et de comités qui ont été nommés en 2012 et en 2013. La plupart d'entre eux assument un mandat de trois ans. Les nominations sont toutes intentionnellement échelonnées, pour veiller à ce que le conseil d'administration compte des membres novices et des membres expérimentés en tout temps.

Le nouveau président de la division Géologie de l'ingénieur, qui remplace Davide Elmo, est **Doug Stead**. Les nouveaux directeurs de sections sont **Jason Pellett** (Vancouver); **Suzanne Powell** (île de Vancouver), **Eric Mohlmann** (Prince George), **Sumi Siddiqua** (intérieur de la Colombie-Britannique), **Mamadou Fall** (est et nord de l'Ontario), **Eltayeb Mohamedelhassan** (Thunder Bay), **Mrinmoy Kanungo** (London), **Jean Côté** (est du Québec) et **Janet Williams** (Terre-Neuve). Je suis également enchanté d'annoncer qu'une initiative vise à former une section au Nouveau-Brunswick, sous l'égide de **Hany El Naggar**, à Fredericton. Les nouveaux présidents des comités permanents de la SCG sont **Michael Porter** (glissement de terrain) et **Roger Skirrow** (géotechnique des transports). Enfin, je suis heureux d'annoncer que **Don Lewycky** est le nouveau rédacteur de la section des actualités de la SCG dans le magazine Geotechnical News. Il succède à Phil Bruch, au terme de ses deux mandants (6 années) à titre de rédacteur. Je remercie tous ces individus d'avoir accepté de consacrer leur temps à ces postes importants et de nous avoir fait bénéficier de leur expérience. Nous rappelons aux membres de SCG qu'ils sont vivement encouragés à adhérer aux divers groupes des sections et qu'ils peuvent se joindre à la plupart des comités.

Tous les ans, la Tournée des conférences pancanadiennes (TCP) de la SCG présente un expert national et un expert international dans certaines sections. À l'automne 2012, **Mike Jefferies** a offert à nos membres trois thèmes de conférence: The State Parameter – it is older than you think and widely applicable; Flaws in the NCEER liquefaction assessment method and how to fix them; et Looking towards Beaufort Sea development – Experience of design, regulation and Reality with the Molikpaq 1984-9.

Le conférencier du printemps 2013 a été **Robert (Bob) Cameron**, de Syncrude Canada Limited. Ses conférences s'intitulaient Case studies

in soil parameter selections for clay foundations et Compaction and design tips for constructing fills at rates up to 25 million m^3/year.

Ed Kavazajian (Ph.D.), professeur à l'Arizona State University, a accepté d'être le conférencier de la TCP à l'automne 2013. Il offrira un choix de six thématiques possibles. Pour savoir s'il fera une présentation à votre groupe, veuillez communiquer avec votre section locale.

De nombreux membres de la SCG ont été honorés par l'Institut canadien des ingénieurs (ICI) lors de son banquet annuel de mai à Montréal : **Peter K. Kaiser** a reçu la Médaille Julian C. Smith; **Ian D. Moore** a reçu la Médaille John B. Stirling; alors que **Iain G. Bruce, Denis LeBoeuf** et **Robert J. Fannin** sont devenus fellows de l'ICI. Félicitations à tous.

Les préparatifs de la prochaine **66e conférence annuelle de la SCG** qui aura lieu du 29 septembre au 3 octobre vont bon train. Les organisateurs ont déjà accepté les articles qui seront présentés.

GéoMontréal sera immédiatement suivie de la **4e conférence canadienne des jeunes géotechniciens et géoscientifiques** (ou cYGEGC). Il s'agit d'un événement de la SCG qui a lieu tous les trois ans où les jeunes (de moins de 35 ans) géoscientifiques et ingénieurs géotechniques peuvent partager leurs connaissances et leurs expériences professionnelles, ainsi que faire du réseautage dans une ambiance décontractée. La cYGEGC aura lieu du 3 au 6 octobre, au Mont-Tremblant. La présidente de cette conférence est **Ariane Locat**. Avec son comité de jeunes professionnels talentueux, elle a réalisé un travail remarquable pour que cet événement ait lieu. La conférence a obtenu plusieurs commandites et de l'industrie et le soutien du Comité sur l'éducation de la SCG. Les divisions Géotechnique des régions froides et Mécanique des roches financent conjointement la présence d'un étudiant à l'événement.

Le Comité sur l'éducation de la SCG et la Fondation canadienne de géotechnique ont établi conjointement un prix à décerner à deux membres de la SCG âgés de moins de 35 ans pour leur permettre d'assister au **5e congrès international des jeunes ingénieurs géotechniciens** qui aura lieu à Paris (France), à l'automne 2013. Nous avons reçu de nombreuses nominations de candidats exceptionnels et avons fini par sélectionner **Nicholas Beier** (University of Alberta) et **Vincent Goreham** (Dalhousie University).

Au plaisir de vous voir à **GéoMontreal 2013**.

Del la part de Richard Bathurst - président

From the Society

Call for Nominations for Awards from the Engineering Institute of Canada (EIC)

Canadian Geotechnical Society (CGS) members are invited to submit nominations for EIC Awards to the Society Secretariat (cgs@cgs.ca) or the Secretary General (vsowacgs@dccnet.com), **no later than July 1, 2013**. All members of the Society are eligible for the awards, prizes and honours from the Engineering Institute of Canada. EIC Policies dictate that all candidates nominated by CGS members for EIC awards, must be members of the CGS.

Nominators are required to provide nomination documents consisting of the following four items:

1. A completed EIC Nomination Form that can be obtained from the EIC Website,
2. A nomination letter,
3. The candidate's Curriculum Vitae, (short form preferred) and
4. A minimum of two and maximum of three supporting letters from colleagues, with at least one letter from an EIC Fellow.

It is recommended that nominators review the full awards details and criteria prior to preparing nominations for the Awards listed below. More information on the procedures, details and schedule for EIC honours and awards can be found in Sections D-1, D-2 and D-3 of the Canadian Geotechnical Society's Awards and Honours Manual. This information is available to CGS members in the CGS Members Section of the CGS Website. CGS members can log-in at http://cgs.ca/login.php, then proceed to Online Member Resources, find CGS Manuals, then proceed to the Awards and Honours Manual. Continue in the Manual to Sections D1, D2 and D3 for detailed information. This information includes a list of past Award Medal members and also Past FEIC members. The Past FEIC members are listed both chronologically and also for convenience, alphabetically.

The CGS Executive Committee reviews all nominations submitted by members, as well as other possible candidates. The selected nominations are then forwarded to the Honours and Awards Committee of EIC for consideration. All constituent societies of EIC participate in this program.

Members of CGS are eligible for the following EIC honours and awards:

- The **Sir John Kennedy Medal** is the most senior award of the Institute. This medal is awarded in recognition of outstanding merit in the engineering profession, or of noteworthy contributions to the

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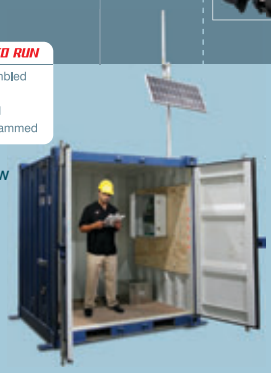

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science of engineering or to the benefit of the Institute.

- The **Julian C. Smith Medal**, established in 1939 by a group of senior members of the Institute to perpetuate the name of a Past President of the Institute. The medal is awarded for "achievement in the development of Canada".
- The **John B. Stirling Medal** was established in 1987 through the generosity of E.G.M. Cape and Company Ltd. to honour a former President of the Company who was President of the Institute in 1952. It is awarded "in recognition of leadership and distinguished service at the national level within the Institute and/or its Member Societies".
- The **Canadian Pacific Railway Engineering Medal** was established in 1988. The medal is presented "in recognition of leadership and service over many years at the regional, branch, section or equivalent levels, within the Institute or its Member Societies".
- The **K.Y. Lo Medal** was created in 1998 and is awarded "to a member of the EIC who has made significant engineering contributions at the international level. Such contributions may include:
  - promotion of Canadian expertise overseas;
  - training of foreign engineers;
  - significant service to international engineering organizations;
  - advancement of engineering technology recognized internationally".
- **Fellowship of EIC (FEIC)**. A member of CGS, of at least 45 years of age, can become a Fellow of the Institute on the grounds of excellence in engineering practice and exceptional contributions to the well being of the profession and to the good of the society.
- **Honorary Membership**. The Council of the EIC may elect to award an Honorary Membership in the Institute to non-members who are not engineers, but who have achieved distinction through service to the profession of engineering.

Provided by Victor Sowa, Secretary General

Nouvelles de la société

Appels de nomination pour les prix de l'Institut canadien des ingénieurs (ICI)

Les membres de la Société canadienne de géotechnique (SCG) sont invités à soumettre des nominations aux prix et médailles de l'ICI au Secrétariat de la société (cgs@cgs.ca) ou à son secrétaire général (vsowacgs@dccnet.com) **d'ici le 1er juillet 2013 au plus tard**. Les membres de la SCG sont admissibles aux prix, médailles et distinctions de l'Institut canadien des ingénieurs. Selon les politiques de l'ICI, tous les candidats mis en nomination par des membres de la SCG à des prix de l'ICI doivent être membres de la SCG.

Les personnes qui soumettent des nominations doivent fournir les quatre documents suivants :

1. un formulaire de l'ICI dûment rempli, qu'il est possible d'obtenir du site Web de l'ICI;
2. une lettre de nomination;
3. le curriculum vitæ du candidat (abrégé, de préférence);
4. au moins deux lettres de recommandation (mais pas plus de trois) de la part de collègues, dont au moins une d'un fellow de l'ICI.

Avant de préparer un dossier, il est recommandé aux personnes qui font une nomination de lire les détails et les critères relatifs aux prix énumérés plus loin dans le texte. Pour plus de renseignements sur la procédure, les détails et le calendrier des prix et distinctions de l'ICI, consultez les sections D-1,

D-2 et D-3 du manuel de la SCG sur les prix et distinctions (Awards and Honours Manual). Ces renseignements sont fournis aux membres de la SCG dans la section du site Web qui leur est réservée. Pour y accéder, il faut ouvrir une session à http://www.cgs.ca/login.php?lang=fr, consulter les ressources en ligne à l'intention des membres, trouver les manuels de la SCG, ouvrir le manuel sur les prix et les distinctions et passer aux sections D1, D2 et D3, qui présentent des renseignements détaillés, dont une liste des membres ayant déjà remporté une médaille ou qui sont déjà fellows de l'ICI. La liste des fellows est présentée en ordre chronologique et, pour des raisons pratiques, en ordre alphabétique.

Le Comité exécutif de la SCG examinera toutes les nominations soumises par les membres, de même que celles d'autres candidats possibles. Les nominations qu'il sélectionnera seront ensuite acheminées au comité des prix et des médailles de l'ICI, pour examen. Toutes les sociétés membres de l'ICI participent à ce programme.

Les membres de la SCG sont admissibles aux prix et distinctions de l'ICI énumérés ci-dessous :

- La **Médaille Sir John Kennedy** est la plus ancienne distinction de l'Institut. Elle est décernée en reconnaissance de mérites exceptionnels ou de contributions dignes de mention dans le domaine de l'ingénierie ou au bénéfice de l'Institut.
- La **Médaille Julian C. Smith** a été établie en 1939 par un groupe de membres émérites de l'Institut, afin de perpétuer la mémoire d'un ancien président de l'ICI. Elle est décernée en reconnaissance d'une « contribution au développement du Canada ».
- La **Médaille John B. Stirling** a été établie en 1987, grâce à la générosité de la société E.G.M. Cape and Company Ltd., pour honorer un ancien président qui était à la tête de l'Institut en 1952. Elle est décernée « en reconnaissance des qualités de chef et des services émérites rendus à l'Institut et/ou à ses sociétés membres à l'échelle nationale ».
- La **Médaille Canadian Pacific Railway Engineering** a été établie en 1988. Elle est décernée « en reconnaissance de plusieurs années de leadership et de services dans les régions, les chapitres ou des niveaux équivalents, au sein de l'Institut ou de ses sociétés membres ».
- La **Médaille K.Y. Lo** a été créée en 1998 et est décernée à « un membre de l'ICI qui a apporté d'importantes contributions à l'ingénierie au niveau internation-

al. Au nombre de telles contributions peuvent figurer :

- la promotion de l'expertise canadienne outre-mer;
- la formation d'ingénieurs étrangers;
- d'importants services rendus à des organismes d'ingénierie internationaux;
- l'avancement d'une technologie d'ingénierie reconnue sur la scène internationale ».

Fellowships de l'ICI. Un membre de la SCG âgé d'au moins 45 ans peut devenir fellow de l'Institut en raison de son excellence en matière de pratiques d'ingénierie et du caractère exceptionnel de ses contributions à l'avancement de la profession et de la société.

Membre honoraire. Le Conseil de l'ICI peut nommer des membres honoraires de l'Institut. Il s'agit de non-membres qui ne sont pas ingénieurs mais qui se méritent cette distinction en raison de services rendus à la profession de l'ingénierie.

De la part de Victor Sowa, secrétaire général

Call for Nominations – CGS President-Elect

The next President-Elect for the Society will be appointed effective January 1, 2014. The person appointed to this position will then become President of the Society for the years 2015 and 2016. It is now time to begin the process leading to this appointment, which will then be confirmed at the 66th Canadian Geotechnical Conference in Montreal on September 29 to October 3, 2013.

In accordance with the By-Laws of the Society, a Nominating Committee was formed to propose a suitable candidate for the President-Elect. The nominating committee consisted of **Bryan Watts** (Chair), **Dennis Becker** (Past-President), **Heinrich Heinz** and **Michel Aubertin** (General Members of CGS).

The Nominating Committee has provided the name of **Mr. Douglas F. VanDine, P.Eng., P.Geo**., as a candidate for the position of President-Elect in 2014, and the President in 2015 and 2016. Mr. VanDine has agreed to be a candidate to serve in these positions. In the accompanying paragraphs, he provides a short statement which outlines his objectives for the Society.

While **Mr. VanDine** is the candidate proposed by the Nominating Committee, other candidates are also welcomed. Any general member of the Society may nominate a candidate for election to the position of President-Elect. Nominations must be received by the Society Secretariat in writing by June 15, 2013. Through the By-Laws of the Society, any such nomination must have the written support of at least 18 general members of the Society and a statement by the candidate expressing willingness to serve as President. Further information can be obtained by CGS members from the Society's Administration Manual available in the Members Section. CGS members can log-in at http://cgs.ca/login.php, then click Online Member Resources, go to CGS Manuals, and proceed to the Administration Manual link.

If there are no additional candidates nominated by June 15, 2013, Mr. VanDine will be elected by acclamation at the September 29, 2013 meeting of the Board of Directors of the Canadian Geotechnical Society in Montreal. If additional candidates are nominated, selection will be by mail-in ballot, and or by electronic ballot. Ballots will be provided to all members of the Society, on or before **July 15, 2013**, with a deadline for receiving completed ballots no later than midnight on **August 15, 2013**. Once all the ballots are counted, the results will be presented at the September 29, 2013 meeting of the Board of Directors of the Canadian Geotechnical Society in Montreal.

Provided by Victor Sowa, Secretary General

NOTE: This notice and the following nomination statement by Mr. VanDine are provided for the purpose of record. This notice and the following nomination statement have been issued to all Canadian Geotechnical Society members in an earlier email notice.

President-Elect's Nomination Statement
Doug VanDine, P.Eng./P.Geo. (BC), FEIC, FEC

Dear Fellow CGS Members

I am honoured to have been selected by the Nominating Committee of the Canadian Geotechnical Society (CGS), to be your President-Elect candidate beginning in January 2014. I accept the nomination. If acclaimed or elected, I am prepared to serve as CGS President for 2015 and 2016.

I am both a Geological Engineer (B.Sc.(Eng)) and a Geotechnical Engineer (M.Sc.(Eng)), who has worked for the federal government, taught at university, and worked for a number of geotechnical engineering consulting firms. Although I have worked on a variety of different geotechnical projects all over Canada, and some abroad, I have specialized primarily in landslides and related fields.

I have been a member of the CGS

Doug VanDine.

since 1972. I was one of the founding members and the second chair of the Engineering Geology Division. I was also one of the founding members of both the Heritage Committee and the Vancouver Island Geotechnical Group, and served for many years on the Landslide Committee. I was honoured to be selected to present the 8th Canadian Geotechnical Colloquium. I am a past recipient of the Thomas Roy Award and what is now the Tony Stermac Award. For several years, I represented the CGS on what is now the Canadian Federation of Earth Sciences and was Treasurer of that organization for many years. I have served as an Associate Editor of the Canadian Geotechnical Journal.

Since 1999, I have been a Trustee of the Canadian Foundation for Geotechnique, serving as its Vice President for 3 years, and then President of the Foundation since 2008. To insure there is no conflict of interest if acclaimed or elected as your President-elect, I will resign as a Trustee of the Foundation and, as previously planned, Dennis Becker will assume the role of President of the Foundation.

I believe this is an interesting time for the CGS. Although the number of geotechnical practitioners in Canada is increasing, the CGS membership has levelled off, even though a number of important issues to the geotechnical profession, both nationally and internationally, are emerging. Nationally, geotechnical engineering is not defined even though it is a commonly used term and is referred to in several pieces of legislation, regulations and other official government documents. There is no discipline of geotechnical engineering recognized in any Canadian professional engineering association, and because there are no geotechnical engineering undergraduate degree programs in any Canadian university, the practice in Canada is essentially only self-regulated, or at best regulated by peer opinion. At least one provincial engineering association is now trying to define geotechnical engineering and is considering establishing minimum academic and/or experiential requirements that could initially be used for self-evaluation by practitioners. Internationally, by 2020, a more formal evaluation and designation may be required for Canadian geotechnical engineers to work abroad. I believe the CGS, although a technical and not a regulatory association, should be involved in these deliberations.

Initially formed in 1947, the CGS is now approaching its 70th anniversary. Nationally and internationally it is held in very high regard. I believe that it's time for the CGS, including its seven divisions, seven committees and 20 sections, to review why the Society exists, how it operates, and make any necessary changes to better serve ALL geotechnical practitioners in Canada. It should be THE "go to"' society for all things geotechnical in Canada, for technical, collegial and social reasons. It should not be a society that geotechnical professionals feel they should maybe join, but a society that they want to join.

Appel de nominations – Président désigné de la SCG

Le prochain président désigné de la société entrera en fonction le 1er janvier 2014. La personne nommée à ce poste occupera ensuite le poste de président de la société pour les années 2015 et 2016. Le temps est venu de commencer le processus de nomination des candidats au poste de président désigné. Le résultat sera annoncé lors de la 66e conférence canadienne de géotechnique qui aura lieu à Montréal du 29 septembre au 3 octobre 2013.

Conformément aux règlements administratifs de la société, un Comité de nomination a été mis sur pied, dans le but de proposer un candidat approprié pour le poste de président désigné. Ce comité était composé de Bryan Watts (président), de Dennis Becker (ancien président), d'Heinrich Heinz et de Michel Aubertin (membres généraux de la SCG).

Le Comité de nomination a proposé M. Douglas F. VanDine, ing. et géol., à titre de candidat au poste de président désigné pour l'année 2014, et de président pour les années 2015 et 2016. M. VanDine a accepté d'être candidat et d'occuper ces fonctions. Plus loin dans le texte, vous pourrez lire sa déclaration de candidat, dans laquelle il énonce brièvement ses objectifs pour la société.

Bien que M. VanDine soit le candidat

proposé par le Comité de nomination, nous accueillons aussi d'autres candidatures. Tous les membres généraux de la société peuvent nommer un candidat à l'élection du poste de président désigné. Les nominations par écrit doivent être reçues par le secrétariat de la société d'ici le 15 juin 2013. Selon les règlements administratifs de la société, toutes les nominations doivent être accompagnées de l'appui par écrit d'au moins 18 membres de la société et d'une déclaration du candidat dans laquelle il indique être disposé à occuper le poste de président. Les membres peuvent obtenir de plus amples renseignements en consultant le manuel administratif de la société dans la section du site Web qui leur est réservée. Il leur suffit d'ouvrir une session à http://cgs.ca/login.php, de cliquer sur l'hyperlien des ressources en ligne, puis sur l'hyperlien des manuels de la SCG et, enfin, sur l'hyperlien du manuel administratif.

Si aucun autre candidat n'est nommé d'ici le 15 juin 2013, M. VanDine sera élu par acclamation lors de la réunion du conseil d'administration de la Société canadienne de géotechnique, qui se tiendra à Montréal le 29 septembre 2013. Si d'autres candidats sont nommés, la sélection aura lieu par bulletin de vote postal et/ou par bulletin de vote électronique. La société fournira des bulletins de vote à tous les membres, au 15 juin 2013 ou avant. Les bulletins remplis devront être retournés d'ici le 15 août 2013, à minuit. Lorsque tous les bulletins auront été dépouillés, les résultats seront annoncés lors de la réunion du conseil d'administration de la Société canadienne de géotechnique, qui se tiendra à Montréal le 29 septembre 2013.

De la part de Victor Sowa, secrétaire général

NOTE : Les présents avis et déclaration de candidat de M. VanDine sont fournis à des fins de tenue de registre. Ces deux documents ont déjà été acheminés à tous les membres de la Société canadienne de géotechnique, dans un avis envoyé par courriel.

Déclaration de candidat au poste de président désigné Doug VanDine, ing./géo., (C.-B.), FEIC, FEC

Chers camarades membres de la SCG,

Je suis honoré d'avoir été sélectionné par le Comité de nomination de la Société canadienne de géotechnique (SCG) comme candidat au poste de président désigné dont l'entrée en fonction aura lieu en janvier 2014. J'accepte la nomination. Si je suis élu par acclamation ou par scrutin, je suis prêt à être le président de la SCG en 2015 et en 2016.

Je suis ingénieur-géologue (B.Sc. (ing.)) et ingénieur géotechnicien (B.Sc.(ing.)). J'ai travaillé pour le gouvernement fédéral, enseigné au niveau universitaire et travaillé pour plusieurs cabinets de consultants en ingénierie géotechnique. Même si j'ai participé à un éventail de projets géotechniques différents partout au Canada ainsi qu'à l'étranger, je me suis principalement spécialisé dans les glissements de terrain et sujets connexes.

Je suis membre de la SCG depuis 1972 et j'en étais l'un des membres fondateurs. J'ai été le deuxième président de la division Géologie de l'ingénieur. J'ai aussi été l'un des membres fondateurs du Comité sur le patrimoine et du groupe géotechnique de l'île de Vancouver, tout en participant durant de nombreuses années au Comité sur les glissements de terrain. J'ai eu l'honneur de présenter le 8e colloque canadien de géotechnique. On m'a décerné le Prix Thomas Roy, désormais appelé Prix Tony Stermac. Pendant plusieurs années, j'ai représenté la SCG à l'organisme qui porte aujourd'hui le nom de Fédération canadienne des sciences de la Terre, dont j'ai aussi été trésorier plusieurs années. J'ai été rédacteur adjoint de la Revue canadienne de géotechnique.

Depuis 1999, je suis fiduciaire de la Fondation canadienne de géotechnique et ai été vice-président pendant trois ans. J'en suis le président depuis 2008. Pour veiller à ce qu'il n'y ait pas de conflit d'intérêts si je suis élu par acclamation ou par scrutin à titre de président désigné de la SCG, je démissionnerai de ce poste et, comme prévu, Dennis Becker assumera les fonctions de président de la fondation.

À mon avis, nous traversons une période fort intéressante pour la SCG. Le nombre de praticiens géotechniques augmente, mais le nombre de mem-

bres de la SCG plafonne, alors même que de nombreuses questions importantes pour la profession géotechnique émergent, tant sur le plan national qu'international. À l'échelle nationale, l'ingénierie géotechnique n'est pas définie, même si l'expression est couramment utilisée dans plusieurs textes législatifs, réglementations et autres documents gouvernementaux officiels. Aucune association d'ingénieurs professionnels ne reconnaît l'existence d'une discipline de l'ingénierie géotechnique et, comme aucune université canadienne n'offre de programmes de premier cycle en ingénierie géotechnique, la pratique canadienne n'est réglementée, essentiellement, que de l'intérieur ou, au mieux, selon l'opinion des pairs. Cependant, une association provinciale d'ingénieurs tente actuellement de définir l'ingénierie géotechnique et envisage d'élaborer des exigences minimales sur le plan de la formation universitaire ou de l'expérience acquise qui pourraient être initialement utilisées par les praticiens pour s'autoévaluer. Sur le plan international, d'ici 2020, les ingénieurs géotechniques canadiens pourraient avoir besoin d'une évaluation et d'une désignation plus formelles pour travailler à l'étranger. J'estime que la SCG, même si elle est une association à mandat technique et non pas de réglementation, devrait participer à ces délibérations.

La SCG a été fondée en 1947 et fêtera son 70e anniversaire d'ici quelques années. Elle est tenue en très haute estime, tant sur le plan national qu'international. Je crois qu'il est temps que la société, ainsi que ses sept divisions, sept comités et 20 sections, réexamine sa raison d'être et son fonctionnement, afin d'apporter les changements nécessaires pour mieux servir TOUS les praticiens de la géotechnique du Canada. La SCG devrait être la société de prédilection pour tout ce qui se rapporte aux géotechniques, pour des raisons techniques, collégiales et sociales. Elle ne devrait pas être une société à laquelle les professionnels géotechniques devraient envisager d'adhérer, mais une société dont ils veulent devenir membres.

De la part de Doug VanDine

Canadian Geotechnical Society Corporate Sponsors

The Canadian Geotechnical Society (CGS) has an important Corporate Sponsorship program. The CGS is pleased to acknowledge the following 2012 Corporate Sponsors listed in alphabetical order:

- Geo-Slope International
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- Morsky Industrial Services
- Naviq Consulting Inc.
- Reinforced Earth Company
- Rocscience
- Stantec
- Thurber Engineering

The Canadian Geotechnical Society (CGS) represents geo-professionals across Canada as the primary technical society for access to technical information, technical journals and other related activities. The Society has a membership exceeding 1,200 engineers, hydrogeologists, geologists and other related professionals. Members are employed in consulting companies, universities, resource development companies, government and non-government agencies, and others.

The CGS offers companies an opportunity to receive services and benefits through a Corporate Sponsorship program. The benefits include the following:

- Use of the CGS logo on corporate literature in combination with the following phrase "Corporate Sponsor of the Canadian Geotechnical Society".
- Recognition as a Corporate Sponsor of the Society in Geotechnical News, and at the annual geotechnical conference.
- Recognition as a Corporate Sponsor on a new page of the CGS Website, including inclusion of the company's logo and a 'hotlink' from the CGS website to the company website.

To view the CGS Corporate Sponsorship program on the CGS Website, and for additional information, refer to http://www.cgs.ca/sponsors.php?lang=en. The sponsorship program provides a significant opportunity to support the Canadian Geotechnical Society and gain additional exposure for your company.

For more information on CGS Corporate Sponsorship or to sign up for 2013, please contact:

Wayne Gibson, P.Eng.
Administrator
Canadian Geotechnical Society
8828 Pigott Rd
Richmond BC V7A 2C4
Tel: 604-277-7527
Toll free: 1-800-710-9867
cgs@cgs.ca

Upcoming Conferences

GeoMontreal 2013
September 29 - October 3
Montreal, Quebec

The Canadian Geotechnical Society (CGS) in collaboration with the International Association of Hydrogeologists (IAH/CNC) and the North American Geosynthetics Society (NAGS), invite you to GéoMontréal 2013, the 66th Canadian Geotechnical Conference and the 11th Joint CGS/IAH-CNC Groundwater Conference. The conference will be held at the Hilton Montreal Bonaventure Hotel, Montreal, Quebec, Canada from Sunday, September 29 to Thursday October 3, 2013.

The theme for **GéoMontréal 2013** is "Geoscience for Sustainability" and will examine how our three associations invest in the progress necessary

to create an innovative and prosperous economy that is ecologically and socially responsible. The organizers intend to weave the conference theme throughout the technical program and social activities and to remind delegates of this important goal in our professional work. The official languages for the conference will be French and English.

Montreal is a city of contrasts, situated on an island with a unique character! Both cosmopolitan and cozy, our metropolis is a window to the world. Full of flavour, it is a mix of deep-rooted traditions, diverse cultures, and languages. The charms of old Europe and the energy of modern North America both radiate from the heart of the city, but it is Montreal's cultural blend that give it such a unique feel.

The Hilton hotel in downtown Montreal borders the city's economic hub as well as the iconic old port. Sights like the Museum of Fine Arts and the Notre-Dame Basilica are within walking distance. Delegates and their guests may also choose to visit numerous tourist attractions during their stay, such as Saint-Joseph's Oratory, the Casino de Montréal, the Olympic Park, the Biodome, the Insectarium, and the city's brand new Planetarium.

For more information, go to www.geomontreal2013.ca

Canadian Young Geotechnical Engineers and Geoscientists (cYGEGC) October 3 to 6, 2013-04-19 Mont Tremblant, Quebec

Join us in Mont Tremblant for the 4th Canadian Young Geotechnical Engineers and Geoscientists Conference (cYGEGC) from October 3 to 6, 2013, a gathering of young engineers and geoscientists sharing technical knowledge and career experiences.

Conference Highlights include:

- exciting technical presentations from the delegates
- 5 keynote speakers with diverse career paths
- A field trip highlighting applications of geoengineering

More information is available at www.cygegc2013.ca

2013 APEGA Summit Awards® Recipients

CGS is pleased to report that Dr. John Sobkowicz, P.Eng., CGS Vice-President Technical in 2011/2012, recently received APEGA's Frank Spragins Technical Award, awarded for recognized integrity, expertise and outstanding accomplishments. The award citation for Dr. Sobkowicz noted the following:

> **Frank Spragins Technical Award - Dr. John Sobkowicz, P.Eng.**
>
> Professional Engineer Dr. John Sobkowicz has successfully taken on some of the most difficult geotechnical engineering projects in Western Canada. In 2011, Dr. Sobkowicz was chosen to be the research leader for an important Alberta Innovates project. He was asked to identify, screen and develop a roadmap of tailings technologies to solve the one-billion-cubic-metre fluid tailings dilemma.
>
> Dr. Sobkowicz published a landmark paper, The Undrained Equilibrium Behaviour of Gassy Sediments, in the Canadian Geotechnical Journal in 1984. The findings from the study and the Sobkowicz-Morgenstern theory are still being used today. He has published more than 50 papers in oil sands engineering, water resources, foundation design and performance, geotechnical instrumentation and natural hazard assessment.
>
> He managed all of the geotechnical investigations for the Bennett Dam Sinkhole project on behalf of BC Hydro and the design and safety evaluations of a number of tailings disposal facilities in the Fort McMurray area.

Editor

Don Lewycky, P.Eng.

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GEO MONTRÉAL 2013

66TH CANADIAN GEOTECHNICAL CONFERENCE / 66E CONFÉRENCE GÉOTECHNIQUE CANADIENNE

September 29 – October 3 2013 / 29 septembre – 3 octobre, Montréal, Québec

The Canadian Geotechnical Society (CGS) in collaboration with the International Association of Hydrogeologists-Canadian National Chapter (IAH-CNC) and the North American Geosynthetics Society (NAGS) invite you to GéoMontréal 2013, the 66th Canadian Geotechnical Conference and the 11th Joint CGS/IAH-CNC Groundwater Conference.

The theme for GéoMontréal 2013 is **"GEOSCIENCE FOR SUSTAINABILITY"** and will examine how our three associations invest in the progress necessary to create an innovative and prosperous economy that is ecologically and socially responsible.

GÉOMONTRÉAL 2013 CONFERENCE PROGRAM HIGHLIGHTS WILL INCLUDE:

- R M Hardy Address presented by Dr. Michel Aubertin (École polytechnique)
- Comprehensive Industry Trade Show with over 50 exhibitors
- Over 600 delegates and more than 300 technical and special presentations over three days!
- 6th annual CGS Gala Awards Banquet and Local Colour Night at Montreal's Centre des sciences in the old port

TENTATIVE TECHNICAL THEMES

Fundamentals
- Engineering Geology
- Foundation Engineering
- Geoenvironmental
- Landslides / Slope Stability / Slope Engineering
- Reliability-based and Limit State Design
- Risk Assessment
- Soil and Rock Mechanics
- Seepage
- Soil Stabilization

Geotechnical
- Revitalization of Aging Infrastructures
- Geohazards
- Retaining Walls
- Mechanically Stabilized Earth Walls
- Brownfields and Redevelopment
- Mine Site Remediation
- Design of Earth Dams
- Design of Clay Liners
- Marine Geotechnics
- Non-textbook Soils / Waste Soils
- Harbour and Shoreline Geotechnics
- Mining Geotechnics
- Cold Regions Geotechnology

Geosynthetics
- Wall Reinforcement
- Confinement in Solid Waste Landfills and Mining Operations
- Drainage and Soil Filtration
- Geosynthetics in Mining Processes
- Water Conservation
- Dams and Levees
- Environmental Engineering
- Case Histories or Failures
- Conveyance and Storage
- Transportation
- Temporary Roads

Multi-Disciplinary
- Geoenvironmental Sustainability
- Instrumentation

Hydrogeological
- Groundwater-Surface Water Interactions and Ecohydrology
- Contaminated Sites and Remediation Technology
- Regional Aquifer Characterization
- Groundwater Management
- Groundwater Quality
- Groundwater Issues Associated with Mineral and Gas Mining
- Impacts of Climate Change on Groundwater Resources
- Isotopic Tracing and Age-dating in Groundwater
- Groundwater and Geotechnics
- General Hydrogeology

The conference will be held at the Hilton Bonaventure in downtown Montréal, Québec.

Please see the conference web site at **www.geomontreal2013.ca** for detailed conference information and to register online. Be sure to register before July 31, 2013 to take advantage of early pricing discounts!

PLATINUM SPONSORS:

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Paolo Gazzarrini

Overture

31st episode of the Grout Line and summer is here at last! For this issue a clarification from Dr. Donald Bruce President of Geosystems, L.P., P.O. Box 237, Venetia, PA 15367, U.S.A., Phone: 724-942-0570, Fax: 724-942-1911, dabruce@geosystemsbruce.com.

The clarification is related to the "refusal and closure" of grouting in a stage, during grouting in rock, using ALT grouting as the guiding philosophy.

I hope you will find this brief article interesting, as I did.

Refusal and closure in rock grouting: Let's get it right!

Dr. Donald A. Bruce

As recently documented in this column, and on the wider stage of international conferences, rock grouting theory and practice in the U.S. has largely evolved towards "Apparent Lugeon Theory" ("ALT") as its guiding philosophy. This statement of fact does not ignore the reality that other approaches — most obviously GIN Theory, as formerly discussed herein— are being applied, and to very good effect in appropriate conditions. Focusing on ALT, however, it is clear that not all its practitioners have fully appreciated some of its subtle but very important nuances.

The rock grouting industry has for long been comfortable with Lugeon Testing as a method for demonstrating the in-situ permeability of rock masses. This comfort level, despite the somewhat involuted, but entirely logical units of the measure (liters per minute per meter at an excess pressure of 10 bars), was elevated by the publication of Clive Houlsby's seminal 1976 paper entitled, "Routine Interpretation of the Lugeon Water-Test." This paper was a Godsend to junior engineers who previously had to navigate through pages of manuals to determine corrections to permeability test results, reflecting flow rates, pipe diameters, bends, estimated elevations of groundwater, and so on. Houlsby gave the grouting world an approach that was admittedly simplified ("routine"), but arguably robust and acceptably accurate.

With the advent of the use of stable grouts (stable not only in bleed but, more critically, in pressure filtration resistance), ALT evolved in the mid-1990's. Credit is due to the late Alex Naudts, building on blocks laid down by DePaoli, et al. in 1992. In essence, such stable grouts do not experience significant changes in rheology as a result of loss of water during injection. Although, of course, continuation of the hydration reactions will effect significant change after periods of several hours, or so. Therefore, the injection of grout itself constitutes a permeability test, of sorts, since the basics of calculation (i.e., flow rate divided by effective pressure divided by stage length) remain in play. These basics are then corrected by a factor, namely the ratio of the Marsh Cone Value of grout to that for water.

When bringing a stage to proper refusal, one wishes to see a progressive reduction in grout flow rate at constant pressure, i.e., a gradual reduction in the Apparent Lugeon Value. This is monitored on the computer screen in contemporary grouting practice, and has been well described in many technical papers. A zero Apparent Lugeon is synonymous with zero grout take, i.e., complete grout refusal. However, zero take is rarely achievable in typical fissured rock conditions, and its relentless unthinking pursuit most often involves lengthy periods of excruciatingly slow injection rates with all the associated mechanical, human and economic frustrations.

This is the hub of the argument and the cause of misunderstanding in certain circles. Whereas the progres-

sive reduction in the Apparent Lugeon Value is a most wondrous and desirable thing to see when monitoring the grouting of a particular stage, an absolute target Apparent Lugeon Value criterion is neither an appropriate target for stage refusal, nor the quantification of the residual permeability of the curtain.

Let's assume that a misguided fellow has established an Apparent Lugeon Value of 5 as a criterion for every stage refusal regardless of depth. So, for a higher stage wherein the refusal pressure is say 5 bars and the stage length is 6 m, the rate of grout flow, at refusal, must be of the order of 15 l/min. But, for a deeper 6 m stage, wherefore the refusal pressure is 10 bars, the rate of grout flow at the same Apparent Lugeon Value of 5 is of the order of 30 l/min. Thus, the lower stage's injection is terminated at a higher rate of flow than the upper, meaning that it has been less effectively and comprehensively treated.

The point is that whereas ALT is a very useful and expressive method for helping to correctly bring a stage to refusal, an Apparent Lugeon Value is not a logical criterion for determining stage refusal. The Stage refusal criterion must be constant, regardless of depth, and should be an absolute value, reflecting constancy of treatment. Incidentally, a refusal criterion of 1 l/min. (over 5 minutes at maximum pressure) is regarded as very "tight," whereas a more liberal criterion of 4 l/min. (over 5 minutes at maximum pressure) may be regarded as acceptable on a project-specific basis.

The second point is that, while ALT aids in bringing a stage to a "good" refusal, it is not a measure of the residual permeability of the treated rock mass. This residual permeability must be measured in dedicated Verification Holes, preferably by multistep Lugeon Tests, using water as the test medium.

Casual grouters may regard this article as little more than splitting hairs or, worse, as sophistry. No, my friends, this issue is fundamental, and would not have been raised unless there were a crying need to do so.

References

Houlsby, A.C. (1976) "Routine Interpretation of the Lugeon Water-Test." Quarterly Journal of Engineering Geology. 9, 303-313.

De Paoli, B., Bosco, B., Granata, R. & Bruce, D.A. (1992) "Fundamental Observations on Cement Based Grouts (1) Traditional Materials (2) Microfine Grouts and the Cemill Process." Proc. ASCE Conf. on Grouting, Soil Improvement and Geosynthetics. (eds. Borden, Holtz & Juran). Vol. 1, 474-499.

Dr. Donald Bruce

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For grouting stories, case histories or only to comment, you can write to me @ Paolo Gazzarrini, paolo@paologaz.com , paologaz@shaw.ca or paolo@groutline.com.

Ciao! Cheers!

Introduction by John Dunnicliff, Editor

This is the seventy-fourth episode of GIN. Three articles this time. They're all self-explanatory, so there's no need for the editor to bore you with introductions. Here's a table of contents:

- A report on the US Society of Dams workshop in Arizona in February on state-of-the-art technologies for monitoring dams and levees, by Christopher Hill and Pierre Choquet.
- The second episode of Field Monitoring Challenges, by Marcelo Chuaqui and Wing Lam.
- An article by me on some on-line sources of information about geotechnical instrumentation.

Lessons learned. I need you

Nobody has responded to my plea for help with GIN, so here's a repeat of the plea:

> A significant number of articles in recent GINs have described new and emerging technologies. It's been exciting for me to learn about these, but I'd now like to take a step towards nuts-and-boltsy things, and lessons learned, primarily lessons learned from unexpected events in the field. All of us in this business have such stories to tell, and if we share them we can learn from each other. So – please – ask yourself whether you could contribute some of these stories for GIN. They don't need to be complex things, and you can refer to "Project X". I well understand that you may have difficulty with employer or client approval, in which case I'm happy to refer to you as "Anonymous", and promise not to disclose your name to anyone.
>
> In the past, I've had very little response to pleas for contributions, and have usually had to rely on arm-twisting. **Please let me hear from you.**

PLEASE let me hear from you. The first step is an abstract – see "How to submit articles" on www.geotechnicalnews.com/instrumentation_news.php. If I don't hear from you, GIN may die.

The April 2103 continuing education course in Florida

There were 64 registrants at the course, and 12 lecturers. 15 countries were represented. Thank you to all registrants and lecturers for participating.

I've decided that there will be no more of these courses in Florida, because age is taking its toll. Perhaps elsewhere. Watch this space!

Closure

Please send contributions to this column, or an abstract of an article for GIN, to me as an e-mail attachment in MSWord, to *john@dunnicliff.eclipse.co.uk, or by mail: Little Leat, Whisselwell, Bovey Tracey, Devon TQ13 9LA, England. Tel. +44-1626-832919.*

Sei Gsund! (Yiddish)

USSD presents workshop on state-of-the-art monitoring technologies

Christopher J. Hill and Pierre Choquet

At the USSD (US Society on Dams) Annual Meeting and Conference in Glendale, Arizona in February 2013, the Committee for Monitoring Dams and their Foundations hosted a workshop titled "State of the Art Technologies for Monitoring Dams and Levees." Fourteen speakers made short presentations about a wide variety of topics, followed by questions and discussion in the seven-hour event. Moderating the workshop were Pierre Choquet of RST Instruments and Christopher Hill of MWD of Southern California.

Two speakers came from Europe to describe the use of fiber optic cables for monitoring. Sam Johansson of HydroResearch in Sweden, and Daniele Inaudi of Smartec in Switzerland described use of fiber optic cables for temperature and strain monitoring, respectively. Johansson made the point that temperature monitoring for dams is a long-established practice to estimate seepage flows, especially in

some European countries, and fiber optic is merely a newer technology for temperature measurements with the added advantage of distributed measurements. Inaudi gave a number of examples of strain measurement especially for dam and levee slope deformation monitoring and showed how the hardware has improved recently. Among these improvements are fiber optic cables designed especially for buried applications as well as improved software.

Four presenters described several geophysical techniques that can be used for dam monitoring. Gordon Anderlini of BC Hydro uses crosshole seismic shear wave tomography to characterize and confirm the remediation of a past sinkhole. Continued monitoring of the sinkhole repairs and embankment dam is done using the simplified common elevation method which has proven to be very repeatable. By monitoring changes in patterns of seismic wave velocity between boreholes, Anderlini monitors changes in void ratio and/or stress with time and expects to get early warning of future sinkhole or internal erosion development.

Phil Sirles of Zonge International, a geophysics company, described how traditional geophysical methods, especially seismic, resistivity and self-potential are used beneficially for assessment of internal erosion, seepage mapping and soil composition in dam embankments and foundations. He also discussed a project that is underway deploying wireless solar-powered self-potential and resistivity instrumentation for early detection of seepage and internal erosion using buried electrodes and passive sensors, thereby enabling "4D" monitoring, i.e., geophysical measurements through time.

William Doll of Battelle presented the background and the current status of an airborne electromagnetic survey system using a low-flying helicopter. This system was tested on a levee segment and showed good correlation with areas that are dominated by clays or sands as well as known sand boil locations.

Yogi Sookhu of Gotham Analytics talked about extensive data communication systems being used to transmit multiple streams of monitoring data along robust paths. One data stream he focused on is from long-wave infrared cameras that may be used to measure wet surfaces and provide notification in the event of sudden enlargement of wet areas.

There were four presentations focused on topics of "traditional" instrumentation. Jay Stateler of the US Bureau of Reclamation talked about anomalous readings and the process by which an anomalous reading is turned into an interpretation of how the dam is performing. Jim Hummert of URS showed results from DamSmart and related products that focus on helping the user manage and graph data. Pierre Choquet of RST Instruments and Christopher Hill of Metropolitan Water District of Southern California presented information about the progress of data acquisition systems focusing on changes in communication topology and energy usage. These improvements are gradually making automatic data acquisition systems more and more practical for users. Finally, in this section, Erik Mikkelsen of GeoMetron made a case for the value of fully-grouted piezometers and described how to install them for best effect.

The final section of the workshop was on deformation measurement. A rail-mounted system for accurate horizontal measurements using terrestrial inSar was presented by Larry Olson, of Olson Engineering. Pieter Bas Leezenbeg of Hansje Brinker, although unable to attend the workshop because of last minute commitments, had prepared slides on satellite-based InSAR applied to deformation monitoring of dams with millimeter accuracy. A 3-D laser scanning system being used for dam deformation measurements by the Metropolitan Water District was shown by Julio Castillo of MWD. Finally, Craig Hewes of Leica made a presentation on using differential GPS and total stations for deformation monitoring.

An abstract of the 14 presentations can be downloaded from the following link: http://mail.rstinstruments.com/DOWNLOADS/USSD2013.pdf . The email address of each presenter is included in the document for anyone who would be interested to obtain their PowerPoint presentation.

Additionally, a slightly modified program based on this workshop will be facilitated at the 81st Annual Meeting of ICOLD (International Commission on Large Dams) in Seattle, WA on August 16, 2014 (http://www.icold2013.org/workshops.html)

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Field monitoring challenges, Episode 2
Unforeseen movements (depth and magnitude)

Marcelo Chuaqui and Wing Lam

Introduction

Continuing our series on Field Monitoring Challenges from the perspective of a specialized monitoring contractor, we present situations where we could not execute a monitoring program as planned or where unexpected challenges arose. Typically the constraints consist of short schedules, limited budgets, no easy access to areas, damage to equipment or instrumentation, lack of understanding of roles and responsibilities, unexpected changes, and conflicting priorities/goals/experience amongst project stakeholders.

In these instances, the situation has to be evaluated and solutions must be implemented to continue providing the monitoring data. The data are valuable for assessing the performance of a design or structure, to verify assumptions and mitigate risk, as well as the safety of all those involved in the construction.

In describing these challenges, potential solutions and the results, we hopefully provide some lessons learned.

Challenge – Unforeseen Movements (Depth and Magnitude)

In the Greater Toronto Area, a roadway was being reconstructed that included widening the road into an adjacent wetland area in difficult ground conditions that included soft peat. The peat line was estimated to extend approximately 13 metres below grade at some points. The soft and variable wetland soils would not be able to provide adequate support and lateral confinement for the road and associated utilities. A permanent retaining wall was to be put in place to limit the potential road and underground utility deformation.

Within the proposed widened portion of the road, two sheet pile walls, approximately 13 metres apart, contained an area of 0.4 MPa filler caissons that were part of a drilled shaft peat removal plan. Within this area, slightly offset from the sheet pile walls, caisson walls would be installed with 20 MPa concrete for king piles and anchor piles and 2 MPa concrete for primary and secondary fillers. Anchor piles would contain double wide flange I-beams. The two caisson walls would be connected together with tie-rods and tiebacks would limit the wall movement. The length of the proposed road widening was approximately 110 metres. Sections of the proposed widening are shown in Figures 1 and 2.

The monitoring plan for the retaining wall system included 15 inclinometers, 68 to 108 feet in length, both attached to piles and borehole locations to measure below ground movements.

Twenty four deep monitoring points were installed in two rows along the length of the proposed road area to measure ground settlement. These were designed in order to be able to add a section to the monitoring point as fill material raised the grade. A base plate was welded to a steel rod section that was allowed to move freely vertically and surrounded by steel pipe sections. Centralizers kept the steel rod section correctly positioned as rods and pipe sections were added using couplers. When readings were required, the protective top cap was removed and a specially machined bar with a reflective target was coupled to the internal steel rod.

Figure 1. Section of proposed widened road showing wetlands.

Figure 2. Section of proposed widened road with piles.

In addition, at two locations 25 metre length multi-point borehole extensometers (MPBXs) were installed that were modified to measure convergence in the backfilled area and reflective pile targets were also placed at the top of sheet piles adjacent to the existing road for monitoring of horizontal and vertical movement of the wall.

A typical section of the monitoring plan is shown in Figure 3.

The ground conditions proved to be more challenging than initially foreseen with the initial assumptions with greater than predicted movements. It was anticipated that the bottoms of the inclinometer casings would be anchored in stable ground and used as a fixed reference point for calculation of movements as is usual practice. The lengths of the casing were determined by the engineer with the available data at the time. Review of the borehole inclinometer plots, in conjunction with the other monitoring data, particularly unexpected divergent movements in the MPBX data, suggested that the bottom of the casings were not in a fixed position but in ground that was experiencing significant movements.

In order to continue to provide valuable subsurface information at these inclinometer locations, the top of the casings were surveyed using a total station and a survey prism pole placed at a specific point on the casing. The survey determined the geodetic position of the top of the casing that was then used as the reference point from which movements were calculated. The resulting data showed a shift of the inclinometer profile adjusted for each reading with the changes in the x and y co-ordinates according to the survey at the top. An example of the adjusted inclinometer plot is shown on Figure 4 showing this shift in the profile.

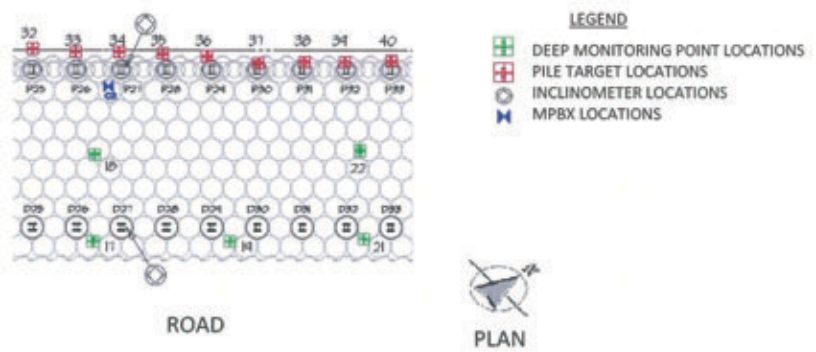

Figure 3. Typical section of monitoring plan.

Lessons Learned

Lesson learned 1: Benefits of a complete monitoring program.

This case history highlights the value

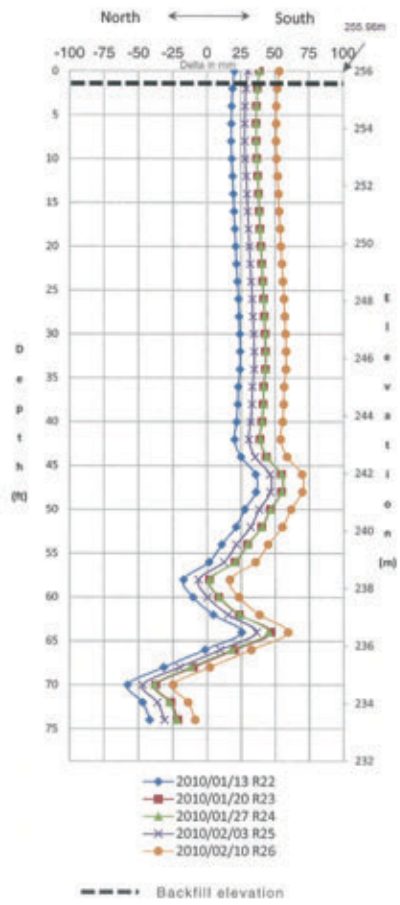

Figure 4. Sample of inclinometer plot.

of a complete instrumentation plan, with more than one instrument type. This permitted cross checking of critical readings across different instrument types that aided in determining a problem with the inclinometer data. The surveying of the top of casing allowed for combined readings to provide a more complete representation of what was happening above and below surface. The deep monitoring points and MPBXs also provided additional redundancy and means of correlation.

Lesson learned 2: Communication and education of needs.

During installation of the borehole inclinometers, there was a lack of understanding of what was required for a successful installation. The field personnel and engineer should have a clear understanding that the instrument should be installed in a stable stratum and what to expect and look for during the drilling of the borehole. If the field conditions differ than expected, communication is important to modify procedures as required to ensure expectations are met.

Lesson learned 3: Be adaptable to the project and client needs.

This case history documents an example of a monitoring problem that occurred after installation and well into the construction project. However, some innovative thinking was able to provide a solution so that subsurface movement of the wall under construction and the ground in the area was available. In would have been easy to simply stop monitoring the inclinometers when it was determined that the bottom of the casings were not anchored in stable ground but understanding their importance and providing the value added service of providing a solution is immeasurable to relationships among stakeholders.

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Some on-line sources of information about geotechnical instrumentation

John Dunnicliff

Introduction

This article is intended as a reference document, and includes the following on-line sources of information about geotechnical instrumentation:

- The U.K. Institution of Civil Engineers on-line manual, Manual of Geotechnical Engineering (MOGE)
- Websites of manufacturers of geotechnical instrumentation.
- Linkedin
- Geotechnical Instrumentation News (GIN)

The article is based on a paper presented during the Eighth Symposium on Field Measurements in GeoMechanics (FMGM), held in Berlin, Germany in September 2011.

The U.K. Institution of Civil Engineers on-line manual, Manual of Geotechnical Engineering (MOGE)

General description of the manual

MOGE consists of nearly 100 chapters, covering a wide spectrum of geotechnical engineering: www.icevirtuallibrary.com/icemanuals/MOGE. There are two chapters about geotechnical instrumentation and monitoring, which update parts of the red book:

- Chapter 94. Principles of geotechnical monitoring. There are three sections:
  - *Benefits of geotechnical monitoring*. The principal technical reasons for recommending a geotechnical monitoring program for a project are described. A common feature of these technical reasons is that monitoring programs generally save money. Allen Marr is the author of this section.
  - *Systematic approach to planning monitoring programs using geotechnical instrumentation*. This 20-step sermon will be familiar to many readers of GIN. It includes the vital topic of how to assign tasks for the construction phase such that high quality data are obtained. The sermon is followed by an example of planning a monitoring program for an embankment on soft ground.
  - *General guidelines on execution of monitoring programs*, including all tasks during the construction phase.

- Chapter 95. Types of geotechnical instrumentation and their usage. There are two sections:
  - *Types of geotechnical instrumentation*. Instruments are described for monitoring groundwater pressure, deformation, load and strain in structural members and total stress. The section includes applications, descriptions of how each instrument works, with schematic diagrams, and various other details intended to help the user.
  - *Usage of Instrumentation*. The section indicates the general role of instrumentation for 12 types of construction projects. For each project type a table summarizes the possible geotechnical questions that may lead to the use of instrumentation, and indicates some of the types of instruments that can be considered for helping to provide answers to those questions.

These two chapters can be downloaded for $30 each. As an alternative to ordering on the website, you can use e-mail, orders@pssc.com, or telephone (978) 829-2544.

Websites of manufacturers of geotechnical instrumentation

Table 1 lists websites of manufacturers with a wide range of products and Table 2 lists websites of manufacturers of specialized products, indicating the product types. I recognize that these tables are bound to be incomplete, despite efforts to be as comprehensive as possible. I've limited these lists to manufacturers, and have made no attempt to include service companies—to include them would be an unachievable challenge.

Table 1: Manufacturers with a wide range of products

Company Name and Country	Website
Ace Instrument Co., Ltd., Korea	www.aceco.co.kr
Dong-A Geovan, Korea	http://geovan.en.ec21.com
Durham Geo Slope Indicator, USA	www.slopeindicator.com
Encardiorite, India	www.encardio.com
Geodata, Austria	www.geodata.com
Geo-instrumentation, France	www.geo-instrumentation.fr
Geo-Instruments, USA	www.geo-instruments.com
Geostar, Taiwan	http://geostar.ueuo.com
Geokon, USA	www.geokon.com
Geonor, Norway	www.geonor.no
Geotechnical Systems, Australia	www.geotechsystems.com.au
Gloetzl, Germany	www.gloetzl.com
Huggenberger, Switzerland	www.huggenberger.com
itmsoil, England	www.soil.co.uk
itmsoil Interfels, Germany	www.interfels.com
Kyowa, Japan	www.kyowa-ei.co.jp
Marton Geotechnical Services, England	www.mgs.co.uk
Roctest, Canada	www.roctest-group.com
RST, Canada	www.rstinstruments.com
SimStrumenti, Italy	www.simstrumenti.com
Sisgeo, Italy	www.sisgeo.it
Solexperts, Switzerland	www.solexperts.com
Telemac, France	www.telemac.fr
Toyoko Elmes, Japan	www.elmes.co.jp/hp-en/E-index.html
Tokyo Sokki Kenkyjo, Japan	www.tml.jp/e/index.html

Table 2: Manufacturers of specialized products		
Company Name and Country	**Products**	**Website**
Alert Solutions, the Netherlands	Systems for online monitoring based on micronano technology sensors	www.alertsolutions.nl
Amberg, Switzerland	3D laser scanning	www.amberg.ch
Applied Geomechanics, USA	Tiltmeters, vibrating wire sensors, dataloggers, fiber optics, GPS	www.geomechanics.com
Avongard, USA	Crack gages	www.avongard.com
BAT, Sweden	Piezometers	www.bat-gms.com
Campbell Scientific, USA	Dataloggers, time domain reflectometry readout units, vibrating wire noise filters	www.campbellsci.com
Canary Systems, USA	Web-based data management software, vibrating wire noise filters	www.canarysystems.com
Cautus Geo, Norway	Web-based data management software	www.cautusgeo.com
Consoil, Sweden	Liquid level settlement gages	www.consoil.se
CMCS, England	Load cells	www.cmcs.co.uk
C.S.G., Italy	Differential multiparametric systems (DMS): in-place inclinometers and multi-piezometers	www.csgsrl.eu
DataTaker, Australia	Dataloggers	www.datataker.com
Druck, USA	Pressure sensors, level meters, flowmeters	www.ge-mcs.com
Fibersensing, Portugal	Fiber-optic sensing systems	www.fibersensing.com
FOS&S, Belgium	Fiber-optic sensing systems	www.fos-s.be
Gage Technique, England	Strain gages	www.gage-technique.demon.co.uk
Gamma Remote Sensing, Switzerland	Gamma portable radar interferometer	www.gamma-rs.ch
Geocomp, USA	Web-based data management software, dataloggers	www.geocomp.com
Geodaq, USA	In-place inclinometers	www.geodaq.com
Geomation, USA	Dataloggers	www.geomation.com
Geotechnical Observations, England	Flushable piezometers	www.geo-observations.com
GeoSig, Switzerland	Earthquake/vibration monitoring	www.geosig.com
GeoTDR, USA	Time domain reflectometry	http://geotdr.com
Getec, England	Liquid level settlement gages, fiber-optic sensing systems	www.getec-uk.com
Gridpoint Solutions, Northern Ireland	3D laser scanning	http://gridpointsolutions.com
Hansje Brinker, the Netherlands	PS-Insar satellite monitoring	www.hansjebrinker.com
Heron Instruments, Canada	Groundwater products	www.heroninstruments.com
Hydroresearch, Sweden	Fiber-optic sensing system	www.hydroresearch.se
Idetec, France	Vibration monitoring	www.idetec.eu
Imetrum, England	Digital image correlation	www.imetrum.com
In Situ, USA	Groundwater products	http://www.in-situ.com

Table 2: Manufacturers of specialized products, cont'd		
Company Name and Country	**Products**	**Website**
Instantel, USA	Vibration monitoring	www.instantel.com
Inventec, the Netherlands	Fiber-optic sensing systems	www.inventec.nl
Jauges Saugnac, France	Crack gages	www.jauges-saugnac.fr
Keynetix, England	Web-based data management software	www.keynetix.com
Kinemetrics, USA	Earthquake/vibration monitoring	www.kinemetrics.com
Laser Solutions, Russia	Fiber-optic sensing systems	www.lscom.ru
Leica Geosystems, USA	Robotic total stations, 3D laser scanning, GPS	www.leica-geosystems.com
Magellan, USA	GPS	www.magellangps.com
Marmota, Switzerland	Fiber-optic sensing systems	www.marmota.com
Maxwell Geosystems, Hong Kong	Web-based data management software	www.maxwellgeosystems.com
Mayes, England	Demec strain gages	www.mayes.co.uk
Measurand, Canada	ShapeAccelArray (SAA) in-place inclinometers	www.measurand.com
Micron Optics, USA	Fiber-optic sensing systems	www.micronoptics.com
Mitre, Canada	Inclinometer software	www.mitre.com
Omnisens, Switzerland	Fiber-optic sensing systems	www.omnisens.ch
Onset, USA	Dataloggers	www.onsetcomp.com
OpSens, Canada	Fiber-optic sensing systems	www.opsens.com
Penny and Giles, England	Displacement transducers	www.pennyandgiles.com
Profound, the Netherlands	Liquid level settlement gauges	www.profound.nl
Reflex, Sweden	Borehole survey equipment	www.reflexinstruments.com
Schlumberger, Canada	Westbay Multilevel Groundwater Monitoring Systems	www.swstechnology.com
Sensornet, England	Fiber-optic sensing systems	www.sensornet.co.uk
Sigra, Australia	Extensometers, stress cells, pressure transducers	www.sigra.com.au
Sireg, Italy	Inclinometer casing	www.sireg.it
Smartec, Switzerland	Fiber-optic sensing systems	www.roctest-group.com
Soilmoisture, USA	Tensiometers (soil suction)	www.soilmoisture.com
SolData, France	Web-based data management software	www.soldatagroup.com
Solinst, Canada	Piezometers	www.solinst.com
Strainstall, England	Load cells and crack gages	www.strainstall.com
Syscom, Switzerland	Earthquake/vibration monitoring	www.syscom.ch
Tektronix, USA	Time domain reflectometry readout units	www.tek.com
Tencate, The Netherlands	Fiber-optic sensing systems	www.tencate.com
Topcon Sokkia, Japan	Robotic total stations, GPS	www.topcon.com
Trimble, USA	Robotic total stations, GPS	www.trimble.com

Table 2: Manufacturers of specialized products, cont'd		
Company Name and Country	**Products**	**Website**
Turner Designs, USA	Fluorometers for flow monitoring	www.turnerdesigns.com
Vibrock, England	Vibration monitoring	www.vibrock.com
Vista Data Vision, Iceland	Web-based data management software	www.vistadatavision.com
VMT, Germany	Ring convergence measurement system for tunnels	www.vmt-gmbh.de/387.html?&L=

Linkedin

www.linkedin.com has numerous Facebook-type networking groups, allowing us to initiate discussions and to post comments. The following are the most relevant for us:

- Geotechnical and Structural Instrumentation & Monitoring
- Geotechnical & Structural Instrumentation
- M.I.T. Monitoring of Infrastructure & Terrain

The first of the three is the most active, and currently has several worthwhile topics.

Geotechnical Instrumentation News (GIN)

For completeness, I should include GIN in this article: www.geotechnicalnews.com/instrumentation_news.php. As you're likely to know by now, there's an index of articles that are on the web, more than 100 downloadable articles, and guidelines on how to submit articles to me for future GINs. As I keep saying—please help to keep this going by sending me an abstract—details are in the guidelines.

Klohn Crippen Berger establishes new graduate scholarship at the University of Alberta

Vivian Giang

(L to R): Ward Wilson, Nicholas Beier, Earle Klohn and Dave Sego. (Courtesy of Jen Stogowski Photography).

On May 6, 2013, the Geotechnical Centre at the University of Alberta celebrated the establishment of the Earle Klohn Graduate Scholarship in Geotechnical Engineering. Klohn Crippen Berger Ltd. (KCB) President & CEO Bryan Watts and scholarship namesake Earle J. Klohn presented the inaugural award to Nicholas Beier at the Fairmont Hotel Macdonald in Edmonton.

KCB donated $150,000 to create an endowment fund which will provide scholarships valued at a minimum of $5,000 annually to outstanding students pursuing graduate research in the field of geotechnical engineering specializing in the geotechnical behaviour or the environmental impact of mine tailings. Klohn is an international authority on the design and construction of tailings dams and has specialized in the design of embankments and the foundations for heavy industrial developments.

At the dinner, Watts made a surprise announcement of an additional donation of $100,000 to the endowment, now worth $250,000. "This scholarship is a testament to Klohn Crippen Berger's vision and commitment to building the next generation of geotechnical engineers," said Dr. Ward Wilson, Professor at the Department of Civil & Environmental Engineering. In his speech, Klohn, who graduated from the University of Alberta with Bachelor's and Master's Degrees in Civil Engineering, recognized the University's strong history of geotechnical education and training and mentoring of geotechnical engineers. "I am honoured that [KCB] would do something like this for me."

Navigating the way toward understanding oil sands tailings

Vivian Giang

WIKIPEDIA defines orienteering as a sport requiring navigational skills using a map and compass to maneuver from point to point in diverse and usually unfamiliar terrain, and normally moving at speed. Dr. J. Don Scott is an avid orienteer, having won the Canadian Orienteering Championship in his age class 12 times, and the sport has taken him to all corners of the world.

However, in the uncharted territory of oil sands tailings behaviour, Scott has proven to be a master orienteer.

In 1980, Scott joined the Faculty of Engineering at the University of Alberta as the Alberta Oil Sands Technology and Research Authority (AOSTRA) Research Chair in Oil Sands. There, he made fundamental contributions to understanding the behaviour of oil sands tailings and was one of the earliest researchers who helped develop the concepts of segregation behaviour and of composite (or consolidated) tailings (CT). One of the lasting legacies of his early research work was the investigation into the settling and consolidation behaviour of oil sands mature fine tailings (MFT) through the observation of two 10-m tailings-filled standpipes. Research engineer Hal Soderberg and geotechnical technologist Gerry Cyre assisted with the development of the standpipe experiments, and a number of graduate students have assisted with the monitoring through the years. This research has led to an unprecedented 30-year-long oil sands tailings experiment which the University of Alberta Geotechnical Centre continues to explore today.

The two standpipes were constructed, installed and filled with tailings in 1982 inside the I.F. Morrison Structures Laboratory at the University of Alberta with funding from AOSTRA. The objectives of these standpipes were two-fold: 1) to observe and evaluate the long-term settling and consolidation response of the oil sands tailings; and 2) to use a finite strain consolidation theory to model the compression behaviour of the tailings in the 10-m standpipes. To study the

Collecting mature fine tailings samples from the top of the standpipe.

Standpipe Facts

- Made of high density polyethylene
- 25-mm thick walls with an inside diameter of 914 mm
- The bottom 0.5 m of each standpipe is encircled by a series of steel bands covered in fiberglass reinforcement to prevent bulging of the plastic due to creep
- The base is a 13-mm thick high density polyethylene plate
- The pore water pressure port and sample ports are aligned down the side of the standpipe
- The standpipes were located in a temperature-controlled building (21°C)
- The base is a 13-mm thick high density polyethylene plate
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Amarebh Sorta working on deconstructing one of the standpipes.

One cubic meter containers for collecting mature fine tailings samples from the standpipes.

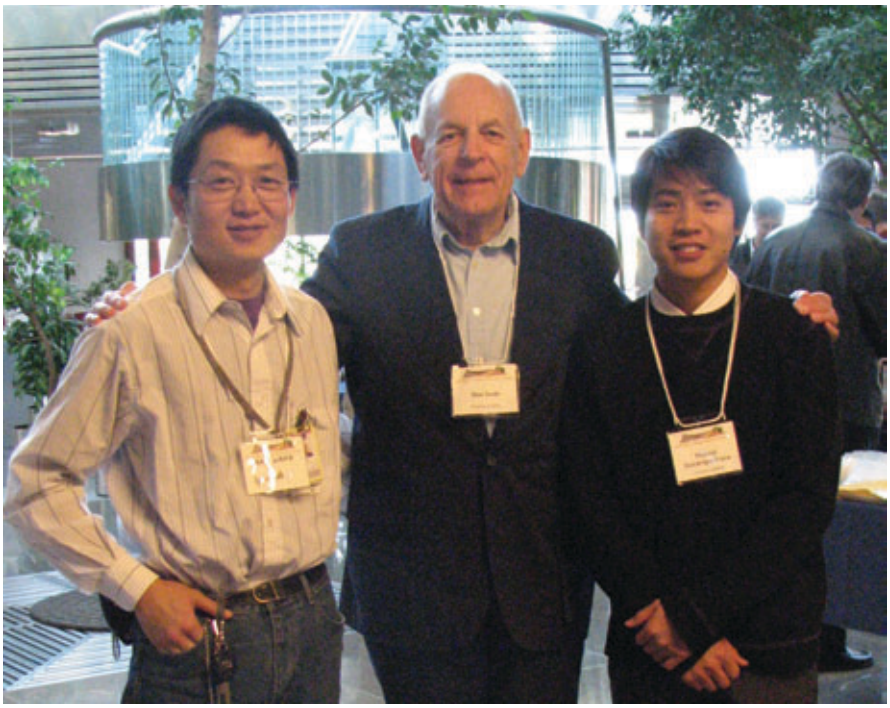
effect of the presence of sand on the consolidation behaviour, Standpipe 1 was filled with mature fine tailings from Syncrude, and Standpipe 2 was initially filled with a mixture of fine tailings and sand (48% sand). However, because the consolidation progress of Standpipe 2 was similar to that of Standpipe 1, and the fact that field applications of CT potentially would use more sand, in November 1984 Scott and Dr. Norbert Morgenstern decided to empty Standpipe 2 and fill it with a new fine tailings and sand mixture (82% sand). From that point on, Standpipe 2 was known as Standpipe 3, and its contents, over time, were similar to that of today's CT.

Scott, who is a Professor Emeritus at the University of Alberta, has been actively involved with the standpipe experiment over the past three decades and trained several graduate students who have gone on to be experts on tailings management in the oil sands industry. Gord Pollock completed his Master's research under the supervision of Scott and was involved during the early years of observing the standpipes. "A unique part of the experiment was simply its scale: the columns are 10 metres tall – or three stories high – and being able to handle all of the material was a challenge," says Pollock.

During the initial observations, the research team saw that the MFT was not responding as expected. "The material appeared to be densifying throughout the height of the column and without any change in effective stress, which was the earliest indication that MFT didn't consolidate like normal slurries. Rather, there appeared to be some type of creep behaviour occuring", Pollock says.

According to Dr. Silawat Jeeravipoolvarn, whom Scott had mentored and co-supervised during his graduate research involving the standpipes 20 years later, the MFT compression mechanism is complex in that the current large strain consolidation test (and ensuing result) cannot be directly applied with the finite strain consolidation theory to predict its behaviour. "The prediction of the compression behaviour of this material likely requires consideration of the time dependent effect that is not properly accounted for in both characterization and theory," says Jeeravipoolvarn.

He says a significant aspect about the experiment was the ability to monitor the standpipes over a long-term period under a well-controlled environment. "No other standpipe containing oil sands tailings has been monitored successfully this long; thus, it provides



Dr. Don Scott with two of his former graduate students Nan Wang (left) and Silawat Jeeravipoolvarn (right).

a great opportunity for the time effect to be explored. This will eventually lead to an improved understanding and theoretical approach to the problem."

In March 2012, the standpipes were decommissioned and deconstructed, and further material testing is currently underway at the Oil Sands Tailings Research Facility (OSTRF) located in Devon, Alberta, with Scott continuing to train and mentor the graduate students in their research. For Jeeravipoolvarn, working with Scott was the best part of being a graduate student. "He taught me all the necessary laboratory skills as well as tips and tricks to perform different tasks. He would guide, but not give the answer – he lets his students form their own thinking and solve the problem themselves."

Along with Jeeravipoolvarn, several students and colleagues fondly remember long working days with Scott, sometimes setting up experiments until the early hours in the morning. Pollock says, "For Don, it's not just a job: he is extremely interested and passionate about research. He keeps abreast on issues that aren't purely geotechnical and finds ways to relate them back to our subject matter."

Through his research acumen and passion, Scott has made considerable contributions to the oil sands industry and is continuing to help navigate the way to better understanding oil sands tailings behaviour.

Acknowledgement

Thank you to Dr. David Cruden and Roger Skirrow who provided the biographical information for this article. Also, thank you to Gord Pollock and Dr. Silawat Jeeravipoolvarn for providing additional information about the history of the standpipe experiment.

A Leader in Geotechnical Engineering

After graduating in Civil Engineering from Queen's University (Kingston, ON) in 1954, Scott joined R.M. Hardy & Associates Ltd. as a soil engineer in Kitimat, BC. He continued his education at the University of Illinois (MSc 1958, PhD 1964) while on the faculty of the University of Waterloo. In 1966, he was appointed Professor of Civil Engineering and Chairman of the Department at the University of Ottawa. He returned to Hardy as a Principal Consultant and Associate in 1978, taking the AOSTRA Research Chair in Oil Sands at the University of Alberta in 1980 and becoming Professor Emeritus in 1993.

At the University of Alberta, he developed laboratory facilities to study the long-term, large-strain consolidation of fine tailings. His numerical models predicting their behaviour have become industry standards. His segregation diagram, developed in 1984, synthesized segregation behaviour and led to the development of non-segregating tailings, now fundamental to modern tailings management schemes. He developed and operated a multi-million dollar research laboratory to examine the effects of the high temperatures and stresses produced in oil sands by the Steam Assisted Gravity Drainage process. He also initiated laboratory studies of geosynthetics to support research on geotextile filters and geogrid reinforced slopes.

Scott has authored over 100 papers on geotechnical engineering, resource geomechanics and geosynthetics. In addition to editing the first *Canadian Foundation Engineering Manual,* he co-authored *Geotextile and Geomembrane International Information Source* with E.A. Richards. He was awarded the 1998 Syncrude Oil Sands Research Prize, an Alberta Science and Technology Leadership Award that honours significant contributions to science and technology in Alberta.

Courtesy of the Geotechnical Society of Edmonton

ISSMGE's Case Histories Journal Releases New Issue

ISSMGE's International Journal of Geoengineering Case Histories is an official journal of the **International Society for Soil Mechanics and Geotechnical Engineering** (ISSMGE) and **Geoengineer.org**, focusing on the publication of well- documented case histories. **It is the first and only refereed journal focusing exclusively on geoengineering practice, while all of its papers and related data are available for free download online!**

The **latest completed issue** of the journal can be found here: *http://casehistories.geoengineer.org/currentissue.html* and includes the following papers:

1. **Title:** Flat Jack Method for Measuring Design Parameters for Hydraulic Structures of the Koyna Hydro Electric Project in India; **Authors:** Keshav Ral Dhawan.
2. **Title:** Large Diameter Long Bored Piles in the Mekong Delta; **Authors:** Bengt H. Fellenius, Nguyen Minh Hai.
3. **Title:** The July 10 2000 Payatas Landfill Slope Failure; **Authors:** Navid H. Jafari, Timothy D. Stark, Scott Merry.
4. **Title:** Embankment Failure in Residual Soils at Nivsar, Ratnagiri; **Authors:** Ashish Juneja, Deblina Chatterjee, Rajendra Kumar.

All case histories papers are also positioned in GeoMap *(http://www.mygeoworld.info/pg/map)* . To learn more about the journal and submit a case history visit http://casehistories.geoengineer.org

Geoengineer.org Opens the Classroom to the Geoprofession

A few months ago, Geoengineer.org developed a platform for hosting web-based class projects online and making them available to the entire geotechnical profession. **This cyber-enabled application aims to facilitate professors and students in the geotechnical engineering field to develop and execute projects as part of courses.**

The first student projects hosted, were part of the "Geoenvironmental Remediation" course of the University of Michigan. The projects were reviewed online by practitioners and academicians, thus helping students learn by making further improvements to their projects. The web-based platform was developed by Geoengineer.org with partial funding from the ASCE Geo-Institute.

View the projects here: *http://www.geoengineer.org/education/web-based-class-projects*

Geoengineer.org develops new ISSMGE.org website

The International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE) and its President Professor Jean-Louis Briaud announced a few months ago the launch of the new ISSMGE website *(http://www.issmge.org)*. ISSMGE.org has now an improved structure and layout and has also improved capabilities to host technical content.

Geoengineer.org is also behind the development and maintenance of other organizational and company websites in the geo-industry. You can learn more about the services offered here: *http://www.geoengineer.org/web-services*

Live Coverage of Geo-industry Conferences

In March, the Geoengineer.org team kicked off a new service for its audience: the "Live Coverage of selected Geo-Industry Conferences". **The first event covered was ASCE Geo-Institute's Geo-Congress 2013, and was attended virtually by more than 1,000 unique visitors!** Live Blogging included posts, photos and videos from technical sessions and the exhibit hall **in real time**, while actual and virtual attendees participated through posts and comments! See the Live blogging page of Geo-Congress 2013: *http://www.geoengineer.org/geocongress2013*

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Assessment of Post-compaction Characteristics of an Unsaturated Silty Sand

Ana Heitor

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Conventional field compaction control methods are effective at the time of placement. However, their measurements are discrete and have a limited depth of investigation, which may not be suitable for post-construction compaction quality assessments of deeper fills or larger surface areas. The use of available non-destructive cost and time effective methodologies, such as shear wave velocity (Vs) surveys (i.e. SASW, spectral analysis of surface waves), offers a valuable alternative to efficiently control compaction during post-construction stages. In fact, while Vs has been used for evaluating the quality of compaction the effect of partial saturation has been neglected. This poses problems for reclaimed fill areas because the ground water level (GWL) is located deeper. In addition, high in situ Vs may not truly represent a higher degree of densification because compacted soil is under unsaturated condition, which means, in situ suction has an important role in controlling the shear strength and thus Vs.

This doctoral thesis addresses the effects of partial saturation in the implementation of a field methodology based on the propagation of Vs and suction for evaluating the compaction quality. It encompasses the use of both small and large strain range in relation to laboratory and field approaches to characterise the behaviour of materials under different compaction conditions, as well macrostructure characterization using X-ray CT-scan techniques. The small strain behaviour was characterized using Bender elements and suction was controlled and measured using an array of different techniques. A new empirical formulation for evaluating the current void ratio or degree of compaction based on shear wave propagation and suction is proposed. The performance of the methodology developed is first calibrated for site-specific silty sand soil in laboratory and then assessed for field site located in Penrith, in which the evaluation of the current compaction degree is of paramount importance for the future redevelopment of the site.

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An Experimental Study on the Deformation Behaviour of Geosynthetically Reinforced Ballast

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The ballast layer is responsible for distributing the applied wheel load to the subgrade soil and maintaining the track alignment. However, upon repeated loading, the ballast deforms and degrades thereby significantly affecting the track performance. Therefore, it is necessary to stabilise the ballasted tracks so that they can carry high-speed trains without creating any major track problem. In this research, an investigation using the large-scale direct shear apparatus was carried out to study the ballast-geogrid interface behavior and establish the effect of geogrid aperture size on the interface shear strength. To realistically simulate the ballast behaviour under cyclic loading, a process simulation test (PST) apparatus was designed in this study. The influence of geogrid on the deformation and degradation of ballast was assessed by conducting the model track tests. Moreover, the study investigated the possible use of optical-fiber Bragg grating (FBG) sensors in monitoring the ballast deformations.

The large-scale direct shear tests reveal that the normalized geogrid aperture size (A/D_{50}) has a profound influence on the shear strength of the ballast-geogrid interfaces. The ratio A/D_{50} is categorized into three key zones: (a) Feeble Interlock Zone, (b) Optimum Interlock Zone, and (c) Diminishing Interlock Zone. The best geogrid aperture size to optimize the interface shear strength is determined to be $1.20D_{50}$. The model track tests reveal that the geogrid successfully arrests the lateral strains in ballast, and that the ideal geogrid placement location to effectively stabilize the track is a function of A/D_{50} ratio. Two new parameters, namely, the Lateral Spread Reduction Index (LSRI) and Geogrid Influence Zone (GIZ) are proposed to assess the performance of geogrid-reinforced ballast, and lateral strain profiles determined. The study further highlights the ability of FBG sensors to capture the deformations in ballast thereby encouraging their use in the monitoring of track stability under operating conditions.

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Performance of Geogrids Stabilised Fouled Ballast in Rail Tracks

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The railway track network plays an essential role of transportation infrastructure worldwide. During operations, the ballast becomes contaminated or fouled due to the infiltration of fines from the surface, mud pumping up from the subgrade, and ballast degradation under repeated train loading. Geosynthetics have been increasingly used in railroads to provide reinforcement and confinement pressure to the layer of ballast. However, the interaction mechanism and behaviour of the geosynthetics and ballast at their interface are not well understood, particularly when the ballast is severely fouled. This research aims to study how the interface between ballast and geogrid copes with fouling by coal fines.

The shear stress-displacement behaviour of fresh and fouled ballast, reinforced with geogrids was investigated through a series of large-scale direct shear tests at low normal stresses from 15 kPa to 75 kPa. When the ballast was fouled by coal fines, the benefits of geogrid reinforcement decreased in proportion to the increasing level of fouling. A novel Track Process Simulation Apparatus (*TPSA*) was used to simulate realistic rail track conditions subjected to cyclic loading. A threshold value of *VCI=40%* has been proposed to assist practitioners in conducting track maintenance. If the level of fouling exceeds this threshold the geogrid reinforcement significantly decreases its effectiveness, and the fouled ballast exhibits pronounced dilation. The Discrete Element Method (*DEM*) was used to study the shear behaviour of fresh and fouled ballast in direct shear testing. Fouled ballast with various Void Contaminant Index (*VCI*), ranging from 20%*VCI* to 70%*VCI*, were modelled by injecting a specified number of miniature spherical particles into the voids of fresh ballast. Based on the research results, an equation incorporating *VCI* was proposed to predict the deformation of fresh and fouled ballast. This equation improves track design and assists in making appropriate and timely decisions on track maintenance.

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Performance Validation of a Permeable Reactive Barrier (PRB) for Treating Acidic Groundwater

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The effectiveness of a permeable reactive barrier (PRB) to remediate contaminated groundwater from acid sulphate soil on the Shoalhaven Floodplain, southeast New South Wales (NSW), Australia was investigated. High concentrations of dissolved aluminium (Al^{3+}), total iron (Fe), and sulphate (SO_4^{2-}) in the groundwater along with low pH were evidence of acidic conditions due to pyrite oxidation at the study site. Groundwater manipulation using engineering solutions such as weirs and modified floodgates drains are not effective in low-lying ASS terrain, as they cannot remediate the acidity already present in the soil nor significantly prevent pyrite oxidation in areas far from nearby drains. This study combined laboratory, field and numerical analyses in order to determine the feasibility and performance of a PRB utilising zero-cost recycled concrete for the remediation of acidic groundwater in ASS terrain.

Long-term laboratory column experiments were carried out using synthetic and real groundwater from the study site. The column experiments investigated the acid neutralisation reactions occurring within the PRB and the precipitation of Al and Fe from the acidic groundwater. Three distinct pH-buffering reactions were ascertained: (i) the dissolution of carbonate/bicarbonate alkalinity from concrete at nearly neutral pH, (ii) the re-dissolution of aluminium hydroxide precipitates at pH ~4, and (iii) the re-dissolution of ferric oxyhydroxides minerals at pH <3. However, carbonate/bicarbonate buffering was the most significant because of the maintenance of near neutral pH and complete removal of Al^{3+} and total Fe from the influent.

Chemical armouring and physical clogging, which are considered the major factors in reducing the efficiency of any reactive material, were also studied by evaluating the duration of buffering periods for maintaining neutral pH and also the changes in physical parameters (e.g. hydraulic conductivity and flow rate) due to mineral precipitation. Chemical armouring by secondary Al- and Fe- precipitates decreased the ANC of the recycled concrete by ~50% compared to its theoretical ANC. Furthermore, high concentrations of Al^{3+} and total Fe caused a rapid decrease in ANC efficiency due to accelerated armouring. Application of larger size concrete aggregates reduced the threat of physical clogging in the pilot-scale PRB. Furthermore, mineralogical and morphological analysis was carried out to characterise the recycled concrete used in the column experiments and the precipitates formed. Correlation between CaO reduction in the armoured concrete and the reduction in ANC validated the decline in ANC by chemical armouring. 3D image analysis

was demonstrated to be a useful tool for the examination of the porous architecture, and the performance of PRB reactive materials in a novel yet quantifiable manner.

A comprehensive field study involved the monitoring of groundwater via piezometers and observation wells, installed up-gradient, within and down-gradient of the PRB, to observe changes in the level of the phreatic surface along with water quality parameters (e.g. pH, electrical conductivity (EC), oxidation reduction potential (ORP), temperature and concentration of anion and cations). Groundwater pH inside the PRB was maintained near neutral throughout the monitoring period. The concentration of Al^{3+} and total Fe were maintained below the Australian and New Zealand Environment and Conservation Council (ANZECC) (2000) criteria, in a similar manner to what was observed in the column experiments. Steady piezometric head observed within the PRB throughout the monitoring period confirmed that chemical and physical clogging did not occur within the PRB to an extent that would affect the permeability of the reactive material.

One-dimensional, simple reactive transport modelling was carried out based on data from a laboratory column experiment, mineralogical analysis of the recycled concrete and the PRB. Numerical modelling using MIN3P provides insights into the neutralisation mechanisms and geochemical evolution of groundwater along a flow path inside the PRB. The ability to make comparisons between the geochemically complex transport scenarios within the column experiments and pilot-scale PRB confirm that it can be used as an analysis tool for investigating the performance of PRBs in ASS terrain.

Overall, this study contributes a better understanding of the acid neutralisation processes occurring inside the PRB for the remediation of contaminated groundwater from ASS terrain and offers novel field, laboratory and modelling techniques to investigate and quantify these processes. The findings from the first pilot-scale PRB using recycled concrete as the reactive material confirms that it is a suitable environmentally friendly and cost-effective alternative to other conventionally utilised techniques (e.g. watertable manipulation, lime neutralisation) for the spot treatment of acidic groundwater in ASS terrain.

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Geotechnical Study of Engineering Behaviour of Fouled Ballast

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When the ballast voids are wholly or partially filled with the intrusion of fine materials, particle breakage and pumping of soft subgrade soil, the track can be considered as being "fouled". In order to ensure acceptable track performance and longevity, it is pertinent to maintain rapid drainage conditions within the ballasted bed. However, fouling reduces the drainage capacity of the ballast, excess pore water pressure can be generated under the passage of fast moving trains (cyclic load), which further compromises track resiliency while contributing to increased maintenance costs. In addition, fouling causes differential settlement of the track and also decreases its load bearing capacity due to the reduction in internal friction of the granular assembly.

A series of large scale hydraulic conductivity tests with specimen size of 500 mm x 500 mm high, were conducted with different proportions of fouling to study the relationship between the extent of fouling and hydraulic conductivity. Since the hydraulic conductivity obtained from laboratory experiments were one-dimensional given that two-dimensional flow conditions may prevail in reality, a numerical analysis was conducted using SeepW (2007a) to quantify the drainage capacity of ballast under different degrees of fouling. Subsequently, a quantitative classification for drainage in relation to the degree of fouling, which is very useful tool for practical engineers, is presented in this thesis.

In order to establish the relationship between the extent of fouling and the associated strength-deformation properties, a series of large scale (300 mm diameter by 600 mm height) monotonic and cyclic triaxial tests were carried out for different levels of fouling for confining pressures in the range of 10-60 kPa. Based on the laboratory findings, a novel empirical relationship between the peak deviator stress and *VCI* has been proposed to assist the practitioner in their preliminary track condition assessment.

A constitutive model for clay fouled ballast is formulated using bounding surface framework under monotonic loading and drained condition. The model is validated with the large scale triaxial experiments carried out in this research.

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Reusable Instrumented Test Pile for Improved Pile Design in Granular Soils

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Caltrans' investment in driven piling to support bridges and other structures has averaged about $25M/year over the last decade. The systems constructed have performed well, but conservatism exists due to uncertainties in soil properties, pile drivability, soil-pile interaction, and pile setup. A new method that could achieve modest saving of 5% in design could save in excess of $1M per annum. This thesis presents the development of a reusable instrumented test pile (RTP) as an in situ testing device for improved pile design in granular soils (coarser than No. 200 sieve). The RTP system consists of short instrumented sections that provide measurements of axial load, radial stress, pore pressure, and acceleration, and are connected in series with standard Becker pipe sections. The RTP – Becker pipe string is driven using the standard Becker pile driving hammer, and the TRP system was designed to handle the high installation stresses in granular soils while retaining sufficient resolution in the instrumentation readings for subsequent analyses of shaft and tip resistances. RTP measurements obtained during driving provide detailed information regarding pile drivability, measurements during static tests capture load transfer along the pile, and measurements during pile setup capture capacity gain over time. The design, fabrication, calibration, proof testing, and full scale field deployment are presented herein.

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Frost Heave: New Ice Lens Initiation Condition and Hydraulic Conductivity Prediction

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Studies on frost heave indicate that significant frost heave observed in the field or laboratory is attributed to ice lens formation associated with water migration to the freezing front and the segregational ice that develops. Hence frost heave prediction models require ice lens initiation criteria and hydraulic conductivity estimation method for the frozen fringe. Existing frost heave prediction methods do involve complex procedures of estimating the hydraulic conductivity. Ice lens initiation conditions by existing methods are not also easy to implement. In fact, some of the exiting frost heave prediction methods lack ice lens initiation condition.

The objective of this thesis is to investigate and develop ice lens initiation criteria and hydraulic conductivity estimation methods that are simple to implement in frost heave prediction. Simple methods, involving the use of SFCC, for predicting ice lens initiation condition and hydraulic conductivity of the frozen fringe have been proposed and verified in this study.

A new fundamental approach is proposed to determine the ice lens initiation condition using the soil freezing characteristics curve (SFCC). It is demonstrated that an ice lens initiates close to the so-called ice-entry value defined using the SFCC. Ice lens initiation conditions for different boundary conditions were determined in a laboratory using the SFCC and were then compared with the ice lens initiation conditions from a one-dimensional open system frost heave tests. The results using the SFCC showed good agreement with the values determined experimentally.

A new approach, using the soil freezing characteristic curve (SFCC), is proposed to estimate the hydraulic conductivity of partially frozen soils. The hydraulic conductivity function for partially frozen Devon Silt is derived using the SFCC and the empirical relationships for hydraulic conductivity estimation method developed by Fredlund et al (1994). The SFCC for Devon Silt is determined from unfrozen water content measurement using time domain reflectometry and temperature measurements inside the soil sample. The results using this novel approach compare well with results presented by others that use different methods to determine the hydraulic conductivity function of partially frozen soils.

Results from previous studies on frost heave indicate the presence of freezing-induced cracks in the frozen fringe (e.g., Arenson et al., 2008). These cracks affect the hydraulic conductivity of the frozen fringe and hence the moisture transfer process during frost heave. The presence of the cracks necessitates the use of a dual porosity model for estimating the hydraulic conductivity function of the frozen fringe. This study proposed a dual porosity model for estimating the hydraulic conductivity of the frozen fringe. Hence, the hydraulic conductivity of the frozen fringe will have two components: hydraulic conductivity of the soil matrix and hydraulic conductivity of the cracks. Methods are discussed to estimate the two hydraulic conductivity components. The hydraulic conductivity of the cracked frozen fringe is the estimated as the weighted average of the two components based on the respective porosity ratio. The proposed dual porosity hydraulic conductivity model is then used to carry out parametric study of the influence of the cracks on the hydraulic conductivity of the frozen fringe. The results indicated that the cracks have considerable influence on the hydraulic conductivity of the frozen fringe while taking only a few percent of the pore space.

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Heat Transfer in Waste-Rock Piles Constructed in a Continuous Permafrost Region

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This study is a part of a field experiment constructed at the Diavik Diamond Mines in northern Canada to investigate water flow, geochemical reactions, thermal and gas transport within unsaturated piles of mine waste rock in a continuous permafrost. Diavik waste rock is categorized by its sulfur content: Type I rock, Type II rock and Type III rock. Three experiment waste-rock pile of 15 m high were constructed to achieve the project objective. Two undercover test piles were referred to as Type I test pile (Type I rock) and Type III test pile (Type III rock). The third test pile is covered test pile in which the Type III rock is covered by a layer of 1.5 m till and 3 m Type I rock. Three drill holes of 40 m depth in a 80 m high pile were also instrumented to reexamine the results of the test piles. This thesis focuses on the thermal aspects of the project.

Thermal measurements in the uncovered piles implied the importance of wind on heat transport. Temperatures within the piles were found to decrease with time and permafrost aggradation near the base and in the bedrock foundation. At the covered pile, temperatures at and below the till cover were frozen. There was no significant impact of wind on temperatures below the cover and heat influx across the cover was small. Bedrock foundation temperature of the covered pile showed a small cooling trend and less fluctuation compared to bedrock foundation of the uncovered piles. Linear stability analysis for the onset of natural air convection in waste-rock piles with physical properties based on Diavik waste rock was also performed. The results indicate that oxidation can create sufficient temperature gradients (or buoyancy forces) to trigger natural air convection.

Ground temperatures of three 40 m drill hole in the 80 m high full-scale pile showed that conduction was dominated and the pile was cooling. According to numerical simulations, using air convection cover (ACC) the 80 m high pile will be frozen for the next 100 years under a proposed climate warming for the site. Furthermore, numerical simulations also showed that ACC can maintain frozen condition within waste-rock piles even though there was a heat release due to sulfide oxidation. This heat release may create natural air convection within waste-rock piles which aids in its removal.

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Design, Deployment, Performance and Assessment of Downhole and Near Surface Monitoring Technology for Geological CO_2 Storage

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Early carbon storage research and development efforts in Canada and elsewhere began with "value-added" projects such as CO_2-enhanced oil recovery or CO_2 enhanced coalbed methane, where the increase in production helps to offset the costs of CO_2 and of its potential long-term storage. These projects provide a valuable opportunity to assess appropriate measurement, monitoring, and verification protocols foe the geological storage component of carbon capture and geological storage technologies. Measurement, monitoring, and verification operations provide confidence that CO_2 has been injected and stored in an environmentally sound and safe manner. Multiple, integrated monitoring instrumentation systems are being deployed in CO_2 field demonstration research projects around the world and will provide experience that can be used in regulatory regimes for future commercial CO_2 sequestration scale projects. The Pembina field was chosen from several fields within Alberta, Canada, for a geological CO_2 storage monitoring pilot study, in which the injection of CO_2 was combined with EOR. As part of the project, an existing wellbore within the study area was used as a dedicated observation well. The design and initial results during cementing of this observation well were reviewed. The experience of implementing monitoring technologies was analyzed in order to assess existing knowledge for deploying downhole instrumentation used for mentoring and verification of CO_2 movements in the subsurface. Analysis indicates that the observation well allows direct monitoring and measurements at reservoir level of multiple variables through geophysical, geochemical, and geomechanical instrumentation, as well as the opportunity to carry out wellbore integrity studies under "in-situ" conditions. A post-cement job and completion analysis that couples downhole measurements, analytical and numerical simulation was conducted to improve future installations. Downhole pressure gauges captured the dynamics of cement displacement and were key elements during post-cement job review and assessments of future well integrity. This research also include the performance assessment of the surface tiltmeter array, an indirect-near-surface measurement technology, deployed in CSEMP – a CO_2 enhanced coal-bed methane pilot project located also in the Pembina Field. The experience and analyses gained from the installations provide valuable insight for CO_2 geological storage monitoring and risk/performance assessment.

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In Situ Stress Magnitude and Core Disking

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Accurate measurement of in situ stress using surface-drilled deep boreholes is a challenge in high stress regimes in which both horizontal stresses exceed the vertical stress. In such cases, hydraulic fracturing and overcoring often yields unreliable results. For such stress regimes core damage and core disking is often observed and these indirect observations were used to constrain the stress state.

Microcracks in cored rock samples are classed as either natural microcracks resulting from geological processes or stress-induced microcracks that are caused by the drilling and sampling process in a highly stressed rock mass. Microcracks in these samples can be identified in laboratory tests using a methodology related to volumetric strain. This methodology was used to quantify stress-induced microcracks in 87 granite-cored samples, obtained in the depth range from ground surface to 1000 m at Pinawa, Canada and Forsmark, Sweden. Digital image analysis of 9 of these samples was used to examine the characteristics of these mirocracks. The results indicate that at depths of less than 200 m, the dominant mode of microcracks can be classed as naturally occurring. The volume of stress-induced microcracks was found to increase linearly with sampling depth with the proportion of grain-boundary, intragranular and transgranular microcracks remaining relatively constant regardless of the depth. However, when the mean in situ stress magnitudes normalized by the laboratory tensile strength was higher than 4, the proportion of intragranular and transgranular microcracks increased significantly for Lac du Bonnet granite. Moreover it was observed that most of the stress-induced transgranular microcracks formed in a plane perpendicular to the core axis. Thus the ratio horizontal to axial transgranular microcrack could be an indicator of the degree of stress-induced core damage.

Core disking is an extreme form of stress-induced microcracking and an indicator of elevated stress magnitudes. Disked cores from boreholes drilled from underground excavations in massive unfractured granite at AECL's Underground Research Laboratory, where the stress magnitudes are known with confidence, were used to establish a relationship between ore disk thickness and the stress magnitude. Relationships were established for three disk thickness categories; (1) thin (t/D<0.2), (2) medium (0.2<t/D<0.4) and (3) thick (0.4<t/D,2.2) and partial disking. The data suggests that core disking initiates when the maximum principal stress normalized to the tensile strength is 6.5. Stress path analyses indicated that tensile stress controlled the onset of disking.

Tensile stress plays a critical role in core disking. Three dimensional numerical analyses were carried out to determine the distribution of these tensile stresses in the vicinity of the advancing drill bit. A methodology was developed to examine the spatial distribution of the maximum, minimum, and average, maximum tensile stress. The analyses were also used to assess the influence of drill-bit geometry on he magnitude and distribution of these tensile stresses. A criterion based on the Averaged Maximum Tensile Stress (AMTS) was found to give good agreement with the thickness of core disks measured on core from 75-mm diameter boreholes. This approach was applied to two sites and found to be in agreement with field observations. According to the criterion, approximately 40% higher horizontal in situ stresses are required for solid core disking than for ring core disking. Numerical analysis using standard drill bit geometry demonstrated that larger, round bits may reduce stress-induced core damage.

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Permeability of Porous Media in the Presence of Gas Hydrates

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Gas hydrates which form at high pressure and low temperature conditions, are solid crystalline compounds comprised of a lattice of water molecules that encage gas molecules. Gas hydrates impact society because of their potential as an immense energy source and their role in submarine geohazards. Economical production of natural gas from hydrate reservoirs crucially depends on the formation permeability and the relative permeability of the sediment to fluid flow. Permeability measurements from natural core samples are difficult owing to core disturbance during retrieval and processing. Laboratory synthesized samples provides a viable alternative with the flexibility to form samples with desired morphology and mineralogy. Unfortunately, very few permeability and relative permeability measurements have been performed and thus the range of media properties and saturations expected in natural hydrate bearing sediments is not available. In the absence of reliable experimental data, numerical reservoir simulators employ theoretical models for permeability prediction. However, experimental verification of the theoretical models is still required.

This thesis focuses on understanding the effect of hydrate formation on the relative permeability of porous media to fluid flow. In doing so, a better way to evaluate the suitability of the existing theoretical models has been developed. It also explores if better permeability prediction can be achieved using a combination of available theoretical models. Finally, an experimental program in which relative permeability of porous media in the presence of carbon dioxide

hydrate was performed and the results analyzed within the proposed framework of modeling and evaluating theoretical permeability predictions.

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Hydraulic Conductivity Measurements for a Champlain Clay Deposit in Lachenaie, Quebec: Theory and Applications

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Precise hydraulic conductivity (K) measurements in aquitards are needed for several types of civil engineering projects. In situ permeability tests are known to produce K values that are more representative of field-scale seepage. Variable-head tests conducted in monitoring wells (MWs) are the most commonly encountered in situ test setting. These tests unfortunately have a long duration (more than a month in Champlain clays). Pulse tests were developed to circumvent this issue. To initiate a pulse test, a small volume of water is injected in the screened portion of a MW while it is isolated by a packer. Typically, a pulse test can be completed in two hours in Champlain clays.

The thesis presents a new interpretation method for pulse tests conducted in saturated soft clays. This new method is based on a joint analysis of cavity expansion and clay volume changes. The new method is based on the superposition of theoretical and experimental non-dimensional velocity graphs. The theoretical type curves were obtained from analytical and finite element solutions (COMSOL) to the Biot equations for the case of 1D axisymmetric flow and for the more general case of partially penetrating wells (2D axisymmetric flow). Compared to existing methods, this new interpretation procedure has the advantages of constraining the range of type curves available for the interpretation of test data, and of being based on a more realistic treatment of deformations.

The new interpretation method was applied to the Lachenaie clay deposit. A strong correlation was observed between the K values obtained from pulse tests and variable-head tests conducted in the same MWs. The large number of in situ and laboratory tests conducted in this deposit allowed a detailed analysis of other issues associated with permeability measurements in Champlain clays to be studied (seasonal head variations, scale effects and hydraulic conductivity predictions).

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A Field Scale Evaluation of Wrinkles in Exposed HDPE Geomembranes

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Intact geomembranes are barriers to advective aqueous flow and are often a key component in the design of composite liner and cover systems. During installation, the combination of solar heating, a high coefficient of expansion, and the stiffness of high density polyethylene (HDPE) causes the geomembrane to expand and buckle, forming wrinkles (waves). Up to 20-30% of the area of the geomembrane may be under hydraulically connected wrinkles, which could substantially increase leakage through the composite liner if there is a hole on or near a wrinkle in the connected network. To quantify wrinkles at the field scale, a technique for low altitude aerial photography and photogrammetric correction was developed.

The technique was used to quantify the geometry of individual wrinkles and the length of the longest hydraulically connected wrinkle at each time for nine field cases. Hand measurements of height and width were conducted at five of the cases. Solar radiation, air and geomembrane temperature was recorded as permitted by site conditions and instrumentation.

The longest measured connected wrinkle was 5330m on a 0.61ha slope. For a 1.5-mm thick geomembrane, the average wrinkle width over a GCL was 0.20-0.23m and 0.24-0.32m over a CCL. The average wrinkle height was 0.06m, and the tallest wrinkle measured was 0.18m. The longest connected wrinkle length was <200m when the sum of the wrinkle lengths was <580m (<8% of the area of the geomembrane was wrinkles). The reported connected wrinkle lengths are significantly longer than previously reported. When input into an existing theoretical leakage solution, these very long wrinkles can explain previous large field measurements of leakage. Results also suggest that limiting the time of day when cover soil is placed and/or reducing the area in which wrinkles can form may greatly reduce the length of connected wrinkles after covering.

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Modelling MSW Leachate Characteristics and Clogging

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A numerical model (BioClog) is developed to examine changes in key municipal solid waste (MSW) leachate characteristics and the porosity of porous media (clogging) as the leachate passes through the drainage layer of a leachate collection system (LCS). The model considers multiple-species reactive leachate transport through porous media. It simulates biofilm growth and loss, deposition of suspended particles, and precipitation of minerals on the surface of porous media. It is used to examine the long-term performance of both the granular porous media and nonwoven geotextiles in LCSs. Modelling of laboratory mesocosm cells filled with gravel usually used in landfills and permeated by landfill leachate shows encouraging agreement between the observed and measured effluent chemical oxygen demand (COD) and calcium concentrations as well as the gravel porosity within the saturated drainage layers. Studies of early generation LCSs involving finger (French) drain systems show that the finger drains are not effective at controlling leachate mounding within the landfill and the calculated leachate mound thicknesses agree well with observed field data. A numerical examination of the recent generation of LCSs, comprised of the granular drainage blanket and perforated drainage pipes, shows that an increase in grain size increases the service life and that increasing the spacing between collection pipes (i.e., the drainage path) decreases the service life of LCSs. Filter-separator layers between the waste and granular drainage layers are shown to increase the service life of LCSs. The modelling results indicate that the calculated clog mass within the saturated drainage layer is dominated by the inorganic material and the calculated service life of LCSs is dependent on the leachate strength examined. Finally, a new practical model for estimating the service life of LCSs is developed and calibrated against the data from the BioClog model. The simplified model could be used by the practicing engineers for estimating the service life and optimizing the design of LCSs in MSW landfills.

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The Analysis of a Deep Excavation in a Gassy Soil

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The study presents a numerical analysis of series of unanticipated events that took place upon the excavation of a landfill in a deep deposit of clayey soil (till) southwestern Ontario, Canada. During the excavation of a landfill cell to be used for waste disposal, unexpected lateral slope movements were observed followed by gas and water venting in several locations . The clayey till is known to be underlain by permeable, natural gas bearing, rock and gas has been diffusing through the clayey deposit over about the last 13,000-15,000 years.

Preliminary 2D and 3D elasto-plastic effective stress analyses using conventional soil revealed the need for model modification to account for other governing factors (gassy soil and hydrofracturing) to be able to explain the mechanism that might have lead to the evolution of gas vents and upward water flow through the thick shale aquitard.

Clayey deposit encountered silty sand lenses at different elevations. The thesis studies the potential of gas exsolution (either prior or during the excavation) within the sand lenses due to upward migration of methane and chloride from the bedrock aquifer through the clay till.

FE model is modified to account for hydrofacturing and gassy soil behavior (for sand lenses). 2D and 3D forensic modeling studies are presented examining the potential causes for the unanticipated movements and the gas and water venting observed during the excavation. The model studies the role of presence of gassy sand lenses and of the presence of discontinuous weak sandy clayey silt layer between the bedrock and the low permeability till on the hydrofracturing path and gas venting.

Finally, a parametric study is conducted to examine the effect of different parameters on the soil behavior when excavated. Recommendations regarding further excavations within the same soil deposit are presented.

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