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Volume 33 • Number 4 • December 2015

GEOTECHNICAL news

Kannaviou Dam, Cyprus: Grouting from the foundation plinth

WIRELESS DATA COLLECTION from geotechnical instruments

Minimum per channel cost | **Extra long battery life** | **Long distance transmission**

Whether you collect data from your geotechnical instruments remotely through a **fully automated** data acquisition system, or by a **semi-automated** (on-site) method, RST Instruments Ltd. has two **wireless solutions** to quickly get you connected to your data.

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rstar ARRAY RADIO SERIES

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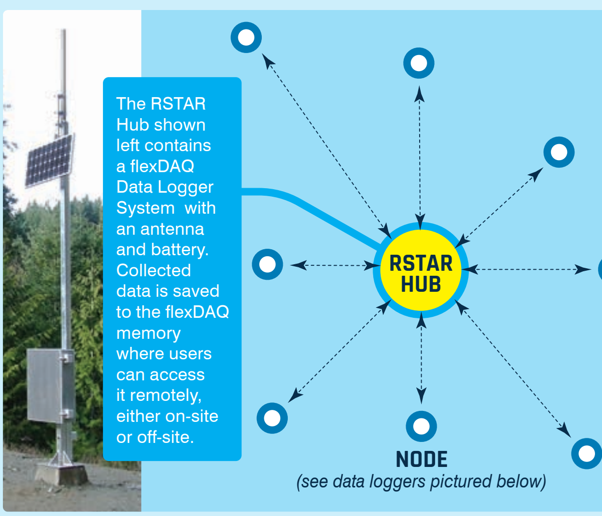

FEATURES

Up to 7 years of battery life from 1 lithium 'D' cell.

Up to 14 km range from Hub to Node in open country. (depending on antenna type)

Up to 255 nodes per RSTAR Hub.

Based on 900 MHz and 2.4 GHz spread spectrum band. (country dependent)

SEMI-AUTOMATED COLLECTION (on-site)

DT LINK WIRELESS

DT LINK is an on-site wireless connection to RST data loggers for quick data collection. Ideal for hard to access areas where the data logger is within line of sight.

Above: A DT LINK WIRELESS data logger, connected to a vibrating wire piezometer and housed in a protective enclosure, has its data collected from a laptop connected to the DT LINK HUB - all within seconds from the convenience of your vehicle.

FEATURES

Safely & easily collect data from data loggers that are in areas with poor access, trespass issues and hazardous obstacles.

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- DT LINK info at: www.rstinstruments.com/dtlinkwireless.html

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CONTENTS

Cover *Kannaviou Dam - Cyprus - Grouting from the foundation plinth.* *See article page 39.*

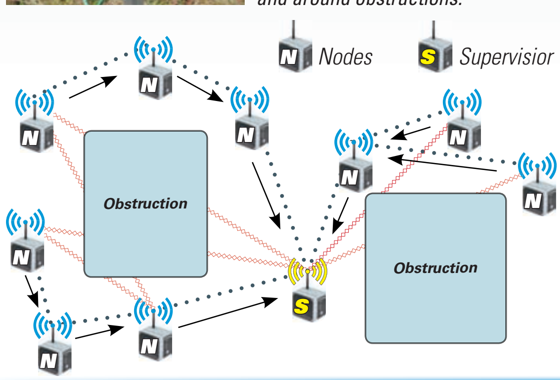
GeoNet Wireless Network

GeoNet is a battery powered wireless data acquisition network compatible with all of Geokon's vibrating wire sensors. It uses a cluster tree topology to aggregate data from the entire network to a single device - the network supervisor. GeoNet is especially beneficial for projects where a wired infrastructure would be prohibitively expensive and difficult to employ.

The network consists of a Supervisor Node and up to 100 Sensor Nodes. Data collected at each node is transmitted to the supervisor. Once there, it can be accessed locally via PC or connected to network devices such as cellular modems for remote connectivity from practically any location.

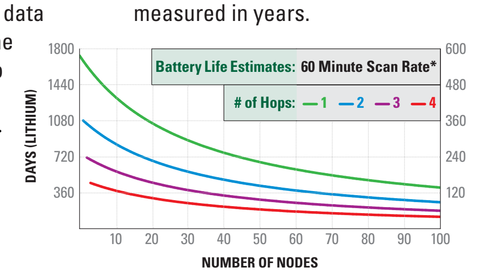
GeoNet Wireless network is self healing and will reconfigure itself to tolerate disturbances to the physical environment.

This topology is more flexible than star networks because it allows data communication to be established over longer distances and around obstructions.



Features & Advantages…

- GeoNet Nodes are comparable in price to a single channel datalogger.
- Uses worldwide 2.4 GHz ISM band.
- Self configuring, easy installation.
- GeoNet will automatically route data around obstructions.
- Nodes separated from network will continue to collect and store data autonomously.
- When network connectivity is re-established the data collected while offline will be transmitted to the supervisor.
- All data collected and sent to the supervisor is also stored on each respective node.
- Long battery life. Most applications measured in years.



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Geopac Provides "Dry Box" Solution to Allow Construction of Underground Parkade in Richmond, BC

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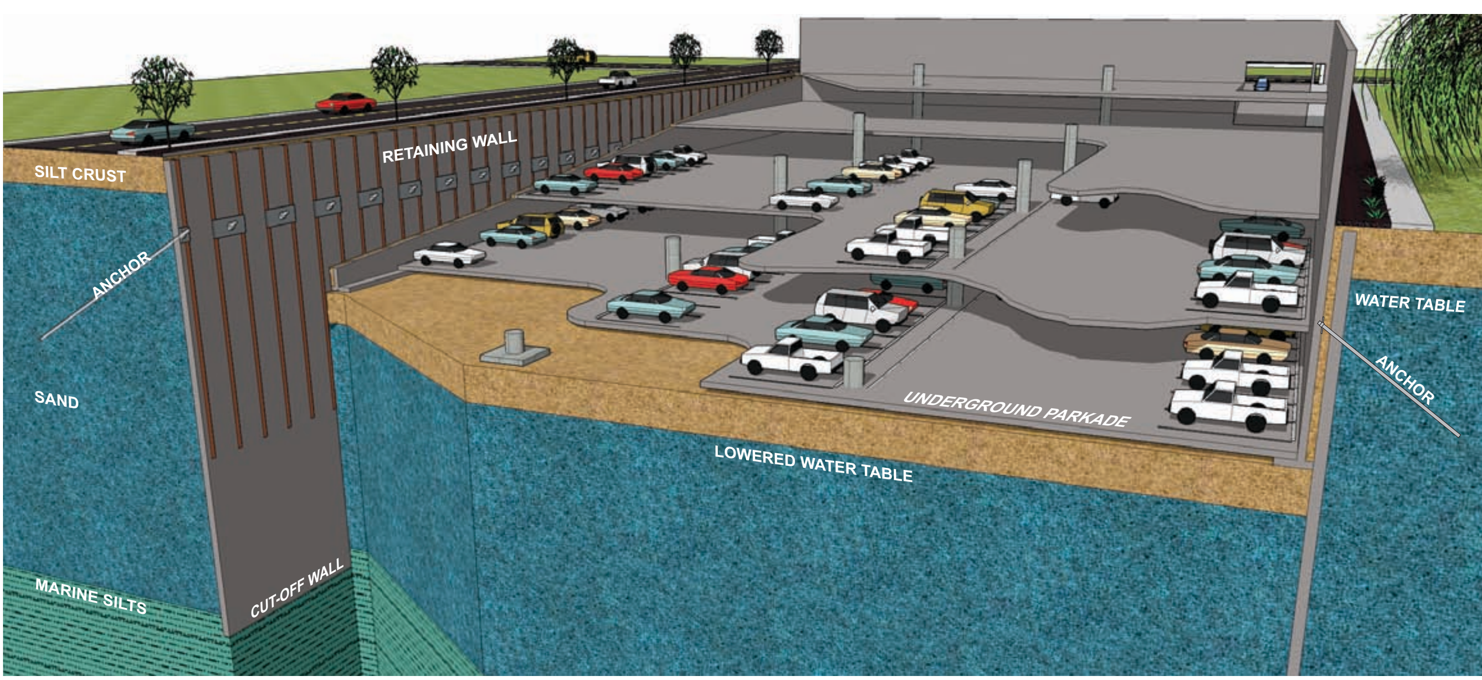

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Message from the President

Doug VanDine, President of Canadian Geotechnical Society

Usually the December issue of CGS News has the President recounting what has been done over the past year. However, this year, I've provided my Annual Report covering July 2014 to June 2015 in December's issue of the CGS-Geotech Info Net (e-News) and on the CGS website (*www.cgs.ca*). For those who don't have access to email or the website, or require a hard copy of that full report, please contact CGS Headquarters at *cgs@cgs.ca* or phone 1 800 710 9867. The following bullets briefly summarizes what the CGS has done since that report was prepared.

- The CGS held a very successful 68th Annual Conference in Quebec City. Merci beaucoup **Jean Côté** and the Local Organizing Committee. The CGS 2015 awards were presented during the conference (see article elsewhere in this issue).
- **Gordon Fenton** of Dalhousie University, Halifax, NS, presented the 96th Cross Canada Lecture Tour in 13 cities. Thank you Gordon and Dalhousie University.
- A new, electronic edition of the Canadian Foundation Engineering Manual is now in the works. Thank you **Angela Küpper,** Vice President Technical, and thanks in advance to the appointed editor **Richard Bathurst** and his Advisory Committee for this upcoming edition of the manual.

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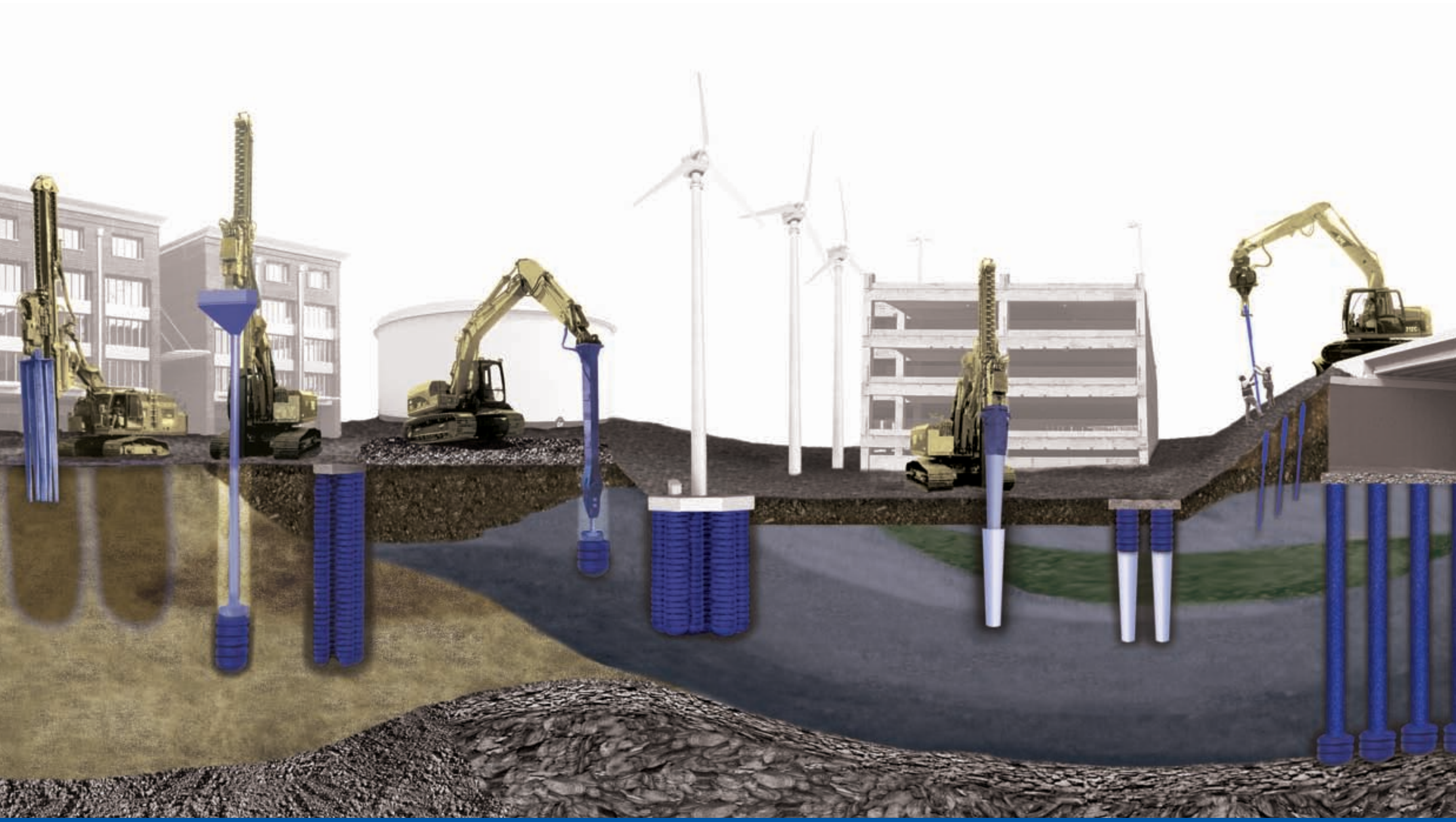

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- As of 2016, the CGS international membership fee will be reduced and the regular, retiree and student membership fees will remain unchanged.
- An Honorary Life Membership has been added to the CGS membership categories. **Gordon McRostie** was presented with the first such membership.
- All students who now register for a CGS annual conference will be given a free CGS student membership for the following year.
- The Geotechnical Society of Edmonton will host the 71st CGS Annual Conference in 2018, after GeoVancouver 2016 and GeoOttawa 2017.
- The 5th Canadian Young Geotechnical Engineers and Geoscientists Conference will be held in Whistler, BC, between September 29 and October 1, 2016, immediately preceding GeoVancouver 2016.
- An online Membership Survey was distributed to determine more about the CGS membership and what it wants from its Society. Thanks to all who responded and the results will be shared with you in the next few months.

What's coming up next? GeoVancouver 2016, the 69th CGS Annual Conference will be held in Vancouver, BC, October 2 to 5, 2016, preceded by the 5th Canadian Young Geotechnical Engineers and Geoscientists Conference in Whistler, BC. In the Spring of 2016, the CGS will have the pleasure of hosting **Dr. Antonio Gens**, from the University of Barcelona, Spain, as the 97th Cross Canada Lecture Tour speaker. Details about locations and scheduling will be forthcoming.

I now want to turn my attention to the CGS as a learned society. I always knew that the CGS was a very active organization, but as President, I have found out how active and involved that our Society is both internally and externally. The figure below is a very abbreviated summary of just how involved the CGS really is and I don't think many members are aware of this (this figure and a description of the acronyms used in the figure are also on the CGS website *www.cgs.ca)*.

The CGS internal organization has 20 Local Sections, 7 Technical Divisions, 7 Standing Committees and the 3 Associates. The upper portion of the figure shows the organizations that are external to, but affiliated with the CGS. The CGS affiliations includes national, North American and international organizations. It's little wonder the CGS is so active!

There are also a number of other like-minded organizations that the CGS could consider becoming affiliated with in the future. These include the Transportation Association of Canada (TAC), the Canadian Dam Association, the Mining Association of Canada and the Canadian National Committee of the International Permafrost Association, to name just a few.

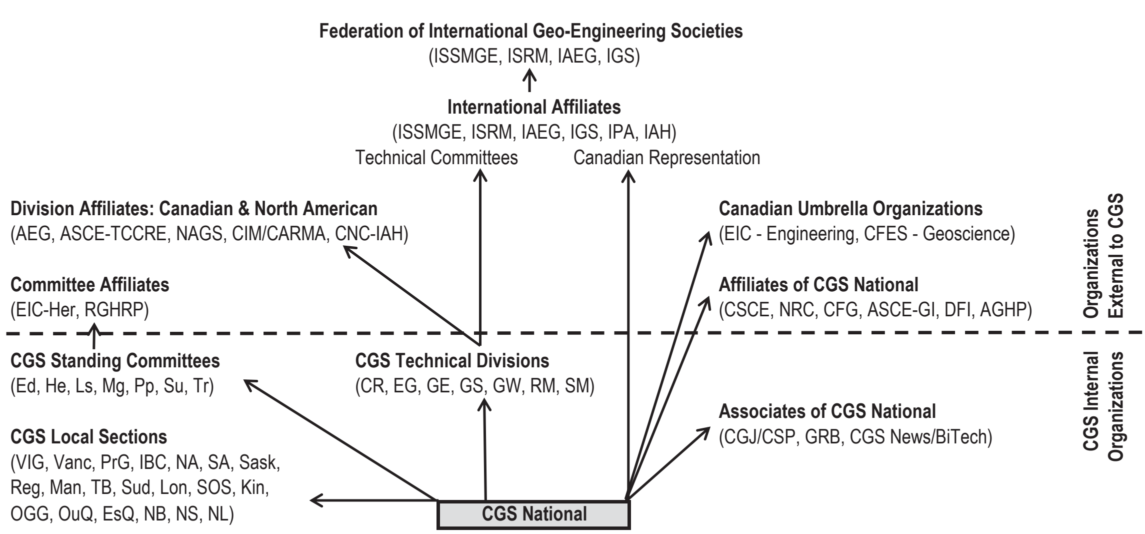
For a learned society such as the CGS, I think it's healthy that we have both active internal groups and to be affiliated with other external organizations that share common interests.

As always, I would be pleased to hear from you on this, or any other geotechnical topic. I can be reached at president@cgs.ca.

Until next time.

Doug VanDine
President - 2015/2016

Canadian Geotechnical Society Organization and Affiliates



(The acronyms are in English only, because most of these organizations do not have an official name in French)

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Message du président

Habituellement, le numéro de décembre de CGS News comporte la récapitulation du président relativement à ce qui a été fait au cours de la dernière année, mais cette année, j'ai publié mon rapport annuel couvrant la période de juillet 2014 à juin 2015 dans le numéro de décembre du Réseau d'information géotechnique de la SCG (bulletin d'information électronique) et sur le site Web de la SCG (*http://www.cgs.ca/index.php?lang=fr*). Si vous n'avez pas accès à un courriel ou au site Web ou si vous avez besoin d'une version imprimée de ce rapport complet, veuillez communiquer avec le siège social de la SCG à l'adresse cgs@cgs.ca ou par téléphone, au 1-800-710-9867. Les puces suivantes résument ce que la SCG a fait depuis la production de ce rapport.

- La SCG a tenu une 68e conférence annuelle très réussie dans la ville de Québec. Merci beaucoup à **Jean Côté** et au comité organisateur local. Les prix 2015 de la SCG ont été présentés durant la conférence (voir l'article à ce sujet dans ce numéro).
- **Gordon Fenton** de l'Université Dalhousie, à Halifax, en N.-É., a présenté la 96e Tournée de conférences transcanadiennes dans 13 villes. Merci à Gordon et à l'Université Dalhousie.
- Une nouvelle édition électronique du Manuel canadien d'ingénierie des fondations est maintenant en préparation. Merci à **Angela Küpper,** vice-présidente technique, et merci à l'avance au rédacteur nommé, **Richard Bathurst**, et à son comité consultatif pour cette prochaine édition du Manuel.
- En 2016, la cotisation des membres internationaux de la SCG sera réduite, et les cotisations des membres ordinaires, retraités et étudiants resteront inchangées.
- Le titre de membre honoraire à vie a été ajouté aux catégories de membres de la SCG, et **Gordon McRostie** a été le premier à le recevoir.
- Tous les étudiants qui s'inscrivent maintenant à une conférence annuelle de la SCG obtiendront gratuitement une adhésion d'étudiant à la SCG pour l'année suivante.
- La Société géotechnique d'Edmonton organisera la 71e conférence annuelle de la SCG en 2018, après GeoVancouver 2016 et GeoOttawa 2017.
- La 5e Conférence canadienne des jeunes ingénieurs géotechniciens et géoscientifiques aura lieu à Whistler, en C.-B., du 29 septembre au

1er octobre 2016, immédiatement avant GeoVancouver 2016.

- Un sondage en ligne à l'intention des membres de la SCG a été distribué pour en apprendre davantage sur ceux-ci et ce qu'ils désirent de leur Société. Merci à tous ceux qui ont répondu à ce sondage. Nous vous en communiquerons les résultats dans les prochains mois.

Que se passera-t-il prochainement? GeoVancouver 2016, la 69e conférence annuelle de la SCG, se déroulera à Vancouver, en C.-B., du 2 au 5 octobre 2016 et sera précédée par la 5e Conférence canadienne des jeunes ingénieurs géotechniciens et géoscientifiques à Whistler, en C.-B. Au printemps 2016, la SCG aura le plaisir d'accueillir le **Dr Antonio Gens** de l'Université de Barcelone, en Espagne, à titre de conférencier de la 97e Tournée de conférences transcanadiennes. Des détails sur les lieux et le calendrier sont à venir.

Je désire maintenant me pencher sur la SCG en tant que société savante. J'ai toujours su que la SCG était une organisation très active, mais à titre de président, j'ai constaté combien notre Société est active et engagée tant à l'interne qu'à l'externe. La figure ci-dessous est un sommaire très succinct de la mesure dans laquelle la SCG est vraiment engagée, et je ne crois pas que beaucoup de membres le savent (cette figure et une description des acronymes utilisés dans celle-ci sont également sur le site Web de la SCG, *http://www.cgs.ca/index.php?lang=fr*). Je m'excuse à l'avance auprès de mes collègues francophones; la figure et le tableau l'accompagnant n'ont pas été traduits.

L'organisation interne de la SCG compte 20 sections locales, sept divisions techniques, sept comités permanents et trois sociétés affiliées. La partie supérieure de la figure illustre les organisations qui sont affiliées à la SCG, mais externes à celle-ci. Les sociétés affiliées à la SCG comprennent des organisations nationales, nord-américaines et internationales. Il n'est pas étonnant que la SCG soit si active!

Il y a également de nombreuses autres organisations ayant la même vision auxquelles la SCG pourrait envisager de s'affilier à l'avenir. Ces organisations comprennent l'Association des transports du Canada (ATC), l'Association canadienne des barrages (ACB), l'Association minière du Canada et le Comité national canadien de l'International Permafrost Association, pour n'en nommer que quelques-unes.

Pour une société savante comme la SCG, je crois qu'il est sain d'avoir des groupes actifs à l'interne et d'être affiliée à d'autres organisations externes partageant les mêmes intérêts.

Comme toujours, je serais heureux de connaître votre opinion à cet égard ou sur tout autre sujet géotechnique. Vous pouvez me joindre à l'adresse president@cgs.ca.

À la prochaine!

Doug VanDine
Président – 2015/2016

From the Society

Canadian Geotechnical Society Awards and Honours for 2015

R.F. Legget Award – Jacques Locat

R.M. Quigley Award – Tony M. Allen, Richard J. Bathurst *"Performance of an 11 m high block-faced geogrid wall designed using the K-stiffness method"*.

Honourable Mentions – Shelley A. Huntley, Arun J. Valsangkar, *"Behaviour of H-piles supporting an integral abutment bridge"*.

Yang Liu, Will P. Gates, Abdelmalek Bouazza, Kerry R. Rowe, *"Fluid loss as a quick method to evaluate hydraulic conductivity of geosynthetic clay liners under acidic conditions"*.

Charles D. Shackelford *"The ISSMGE Kerry Rowe Lecture: The Role of Diffusion in Environmental Geotechnics"*.

G. Geoffrey Meyerhof Award – Richard Bathurst, Royal Military College of Canada.

Thomas Roy Award – Mark Diederichs, Queen's University.

Roger J. E. Brown Award – No award issued in 2015.

John A. Franklin Award – Hani Mitri, McGill University.

Geoenvironmental Award – No award issued in 2015.

Geosynthetics Award - No award issued in 2015.

Robert N. Farvolden Award (Joint Award with IAH-CNC) – Diana Allen, Simon Fraser University.

Robert Schuster Medal – David Cruden, University of Alberta.

Graduate Student Paper Award

1st Prize: Amy Rentz, *"Field performance of exposed geosynthetic composite liner systems: Down-slope bentonite erosion from a geosynthetic clay liner (GCL)"*, Civil Engineering, Queen's University, Dr. Kerry Rowe.

2nd Prize: Eliza Rozina, *"Dewatering in laboratory simulation of a multilayer deposit of in-line flocculated mature fine tailings"* Civil and Environmental Engineering, Carlton University, Dr. Paul Simms.

Undergraduate Student Report (Individual)

1st Prize: Helena Diao, *"Evaluating Methods for Assessing Rotational Stability of Surface Rock Wedges"*, Civil and Environmental Engineering, University of Waterloo, Dr. David Brush.

2nd Prize: Brian Wazney, *"Review and Application of Limit States Design (LSD) for Winnipeg Riverbanks"*, Civil Engineering, University of Manitoba, Dr. Marolo Alfaro.

Undergraduate Student Report (Group)

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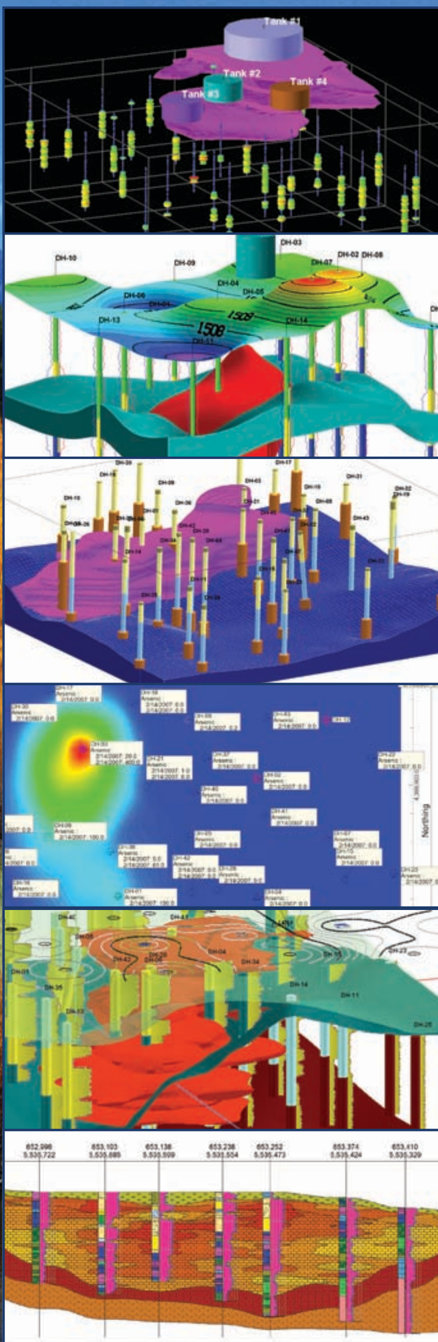

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DGSI's track monitoring systems help maintain railroad safety by monitoring settlement and twist. The systems are installed on railroad tracks that cross landslides or washout areas. They are also installed on tracks affected by nearby construction activities either adjacent or beneath the track.

Digitilt Classic Inclinometers

The Digitilt Classic Inclinometer System consist of a control cable marked in feet or meters, a Datamate II readout. DigiPro2 software and a pulley assembly are options to complete a system is designed to measure subsurface deformations in vertical and horizontal boreholes.

Strain Gauges

DGSI's strain gauges are used to monitor strain in concrete and steel structures and can be easily installed in the field. Strain gauges are durable to minimize long-term drift and changes in calibration. DGSI's strain gauge readings are obtained using a vibrating wire readout.

Inclinometer Casing

DGSI's inclinometer casing is considered to be the strongest, most reliable casing available. Offered in three diameters and five coupling styles, all of DGSI's casing features precision grooves and provides superior resistance to twisting and bending.

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Piezometers

DGSI's VW piezometers are used to monitor pore-water pressure. They are available in standard configuration as well as push-in, vented, pneumatic and heavy-duty models.

Data Recorders, Loggers

DGSI offers a wide range of data recorders and loggers to monitor geotechnical sensors and instrumentation. DGSI can configure data systems and monitoring programs to customer specifications in order to reduce the time and expense required to deploy data acquisition systems.

Extensometer & Settlement Cells

DGSI's line of extensometers include magnet extensometers, digital tape extensometers, and rod extensometers and are used to monitor settlement. DGSI's Settlement Cells are used to monitor a single point of settlement.

Atlas Web-Based Monitoring

Atlas web-based monitoring software solves the two major problems of data acquisition; the timely processing of data and the distribution of results to others. DGSI can provide system integration of sensors, data logger and web-based monitoring on a 24/7 basis.

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NOVA METRIX

1st Prize: Kate Briscoe, Kate Thompson, Gordon Goode, Kirandeep Dhillon, *"Tailings Management Facility Design Final Report"*, Civil Engineering, Queen's University, Dr. David Noonan.

2nd Prize: Gavin Black, Savanna Herman, Shammai Ugalino, Aron Zahradka, *"Long Lake Project: Tunnel Versus Rock Cut Design Option Analysis"*, Earth, Ocean & Atmospheric Science, University of British Columbia, Susan W. Hollingshead.

Canadian Foundation for Geotechnique Michael Bozozuk National Graduate Scholarship – Christopher Kocur, Western University.

A.G. Stermac Awards

J. Paul Dittrich, Principal, Golder Associates Ltd.

David M. Gauthier, Senior Geological Engineer/Geoscientist, BGC Engineering Inc.

A. Wayne Clifton, President, Clifton Associates Ltd..

CGS R.M. Hardy Keynote Address – Dr. Jean-Marie Konrad, Professeur, Université Laval.

Canadian Geotechnical Colloquium – Dr. Greg Siemens, Associate Professor, Queens University.

Cross Canada Lecture Tours – Nick Sitar (Spring 2015), **Gordon Fenton** (Fall 2015).

Awards From the Engineering Institute of Canada (EIC)

Fellowship of the Institute (FEIC) – Alex Sy, Vice President, Klohn Crippen Berger.

Fellowship of the Institute (FEIC) – Mark Diederichs, Professor, Queens University.

Provided by Lisa McJunkin, CGS Administration

CGS Membership Registration for 2016

If you haven't already renewed your Canadian Geotechnical Society membership for 2016 or want to join, now's the time. Visit *www.cgs.ca* <Membership>. There are no increases in membership fees for 2016 and in fact, fees for international members have been decreased!

Membership benefits include:

- online access to the monthly Canadian Geotechnical Journal including all past issues, and a special price for the printed Canadian Geotechnical Journal
- online and printed copies of the quarterly Geotechnical News, including CGS News
- the monthly electronic CGS Geotechnical Information Net
- online access to all past CGS Conference proceedings and some special lectures
- special price for all CGS conferences
- information on the spring and fall CGS Cross Country Lecture Tours
- membership in one or more of 7 CGS technical divisions and associated international societies
- involvement in one of 20 CGS local sections
- involvement in any of the 7 CGS standing committees
- involvement in THE society for all Canadian geotechnical professionals

We welcome all new and renewing members and look forward to your participation in 2016. We also encourage you to recommend the CGS to a friend or colleague. Let's continue to improve the benefits that the CGS offers our profession.

Members in the News

The Canadian Geotechnical Society Presents its First Honorary Life Membership to Mr. Gordon C. McRostie

At the 68th Annual Conference of the Canadian Geotechnical Society in Quebec City, **Mr. Gordon C. McRostie** P.Eng. was honoured by the CGS and his Ottawa colleagues with the Society's first Honorary Life Membership. CGS President **Mr. Doug VanDine** told the approximately 650 in attendance at the presentation that "Gordon exemplifies a life-long contribution and dedication to the Canadian Geotechnical Society and to the geotechnical profession in Canada".

Gordon McRostie graduated with a civil engineering degree from the University of Toronto in 1944. In 1950, he began his own geotechnical engineering practice in Ottawa, one of the first geotechnical consulting firms in Canada. By 1960 he had a small staff, a soil testing laboratory, a drill rig, and was carrying out about 50 projects per year. His consulting practice continued to grow and has carried out a total of approximately 3,000 projects mostly in eastern Canada, but several abroad, including the Canadian embassy in Berlin, Germany. In 2005, his firm merged with Golder Associates Ltd.

In 1961, Gordon helped form the **Geotechnical Engineering Division of the Engineering Institute of Canada**, which in 1972 became the **Canadian Geotechnical Society.** In 1963, Gordon was one of 10 geotechnical professionals who financially backed the first year of the **Canadian Geotechnical Journal**, a journal that is now in its 52nd year and recognized as one of the best geotechnical journals in the world.

In 1947, Gordon helped organize in Ottawa, the **1st Canadian Conference on Soil Mechanics and Foundation Engineering**, the forerunner of the CGS Annual Conference. He was one of forty to attend that event and has since attended 66 of the 68 CGS annual conferences. He was on the organizing committees of a number of those conferences and now 93 years old, Gordon is on the organizing committee of the 70th CGS Annual Conference to be held in Ottawa in 2017.

A recipient of many awards, Gordon was presented in 1997 with the highest award of the Canadian Geotechnical Society, the **R.F. Legget Medal**, recognizing his long-standing support of the CGS and the geotechnical community.

Gordon credits his longevity to an active lifestyle, besides being an active geotechnical engineer. He ran 4 to 5 kilometres every day for 50 years, was an avid skier and hiker and has travelled around the world three times. For his 90th birthday, went skydiving!

For all the above reason, the Canadian Geotechnical Society is pleased to present Mr. Gordon C. McRostie with its first Honorary Life Membership.

La Société canadienne de géotechnique présente son premier titre de membre honoraire à vie à M. Gordon C. McRostie

Le 21 septembre dernier, à la 68e conférence annuelle de la Société canadienne de géotechnique (SCG) tenue dans la ville de Québec, **M. Gordon C. McRostie** a été honoré par la SCG et ses collègues de la région d'Ottawa. Le président de la SCG, M. Doug VanDine, a présenté le premier titre de membre honoraire à vie de la Société à M. McRostie. En présentant ce titre, le président VanDine a déclaré aux quelque 650 personnes assistant à la présentation que « Gordon incarne une contribution et un dévouement de toute une vie envers la Société canadienne de géotechnique et la profession géotechnique au Canada. »

Gordon McRostie a obtenu son diplôme en génie civil de l'Université de Toronto en 1944. En 1950, il a ouvert son propre cabinet de géotechnique à Ottawa; il s'agissait d'une des premières sociétés d'experts-conseils en géotechnique au Canada. En 1960, l'entreprise avait un petit effectif, un laboratoire d'analyse des sols, un appareil de forage et il réalisait environ 50 projets par année. Jusqu'en 2005, année à laquelle sa société a fusionné avec Golder Associates Ltd, son entreprise a continué de croître, ayant réalisé environ 3 000 projets, principalement dans l'Est du Canada, mais aussi à l'étranger, y compris à l'ambassade canadienne de Berlin, en Allemagne.

En 1961, M. McRostie a aidé à former la Division de **géotechnique de l'Institut canadien des ingénieurs**, qui est devenue en 1972 la **Société canadienne de géotechnique**. En 1963, il a été l'un des dix professionnels de la géotechnique qui ont appuyé financièrement la première année de la **Revue canadienne de géotechnique**, une revue qui en est maintenant à sa 52e année et qui est reconnue comme l'une des meilleures revues de géotechnique au monde.

M. McRostie a aidé à organiser la **1re Conférence canadienne sur la mécanique des sols et l'ingénierie des fondations** (le précurseur de la conférence annuelle de la SCG) à Ottawa, en 1947, et il a été l'une des 40 personnes à y assister. Depuis, il a participé à 66 des 68 conférences annuelles de la SCG et a fait partie du comité organisateur d'un grand nombre d'entre elles. Maintenant âgé de 93 ans, il est membre du comité organisateur de la 70e conférence annuelle de la SCG qui aura lieu à Ottawa, en 2017.

Lauréat de nombreux prix, M. McRostie a reçu en 1997 le plus important prix de la Société canadienne de géotechnique, la **Médaille R.F. Legget**, en reconnaissance de son soutien de longue date à la SCG et à la communauté géotechnique.

M. McRostie croit que sa longévité est due à un style de vie actif. En plus d'être un géotechnicien très impliqué, il a couru de quatre à cinq kilomètres chaque jour pendant 50 ans; il était aussi un skieur et un randonneur invétéré, a fait le tour du monde trois fois et, pour son 90e anniversaire, a sauté en parachute.

Pour toutes ces raisons, la Société canadienne de géotechnique est heureuse de présenter son premier titre de membre honoraire à vie à M. Gordon C. McRostie.

Michel Aubertin
CGS Executive Director

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Division & Committee News

Call for Nomination for Robert Schuster Medal

The Robert Schuster Medal is a joint award shared between the CGS (Landslide Committee and Engineering Geology Division) and the Association of Environmental and Engineering Geologists (AEG). This award honours CGS and AEG member, **Dr. Robert Schuster** (b 1927), who has had a distinguished career, primarily related to geohazards.

The medal recognizes outstanding contributions to geohazards research, teaching and/or professional practice in North America. The award is typically awarded to a CGS then an AEG member in alternate years, but for logistical reasons it is to be awarded to a CGS member in both 2015 and 2016.

Past medal winners include:

2007 - Robert L. Schuster

2008 - Oldrich Hungr

2009 - Barry Voight

2010 - Norbert R. Morgenstern

2011 - No Award

2012 - Derek Cornforth

2013 - Jacques Locat

2014 - Keith Turner

2015 - David Cruden

The Nomination Committee is now calling for nominations of a CGS member for the 2016 Robert Schuster Medal. Nominations from CGS members should comprise a letter of nomination and a 2-page resume, and should be sent to CGS Headquarters (cgc@cgs.ca, or by mail at 8828 Pigott Road, Richmond, BC, V7A 2C4) by January 15, 2016. For further information, contact **Michael Porter**, Chair of the CGS Landslide Committee *MPorter@bgcengineering.ca*.

Upcoming Conferences and Seminars

69th Canadian Geotechnical Conference
October 2 to 5, 2016
Vancouver, British Columbia

Call for Abstracts

The **Vancouver Geotechnical Society** and the **Canadian Geotechnical Society** invite you to the 69th Canadian Geotechnical Conference. The conference will be held from October 2 to 5, 2016 in Vancouver, British Columbia, Canada. It will cover a wide range of topics, including specialty sessions that are of local and national relevance to the disciplines of geotechnical and geo-environmental engineering. In addition to the technical program and plenary sessions, the conference will include a complement of short courses, technical tours, local excursions and entertaining social activities.

The official languages for the conference will be English and French. Vancouver is well known for its beautiful scenery, which encompasses the Coast Mountains, the Fraser River Delta and the Strait of Georgia. The city has been host to many national and international events, including the 2010 Winter Olympics. This breathtaking surrounding lends itself to a wide variety of geological conditions and geotechnical challenges, including high seismicity, steep terrain and soft soils.

The Conference will be held at the picturesque Westin Bayshore Hotel which is well situated between the downtown business district and Stanley Park.

The theme of the Conference is **"History and Innovation"**, which will recognize the historical achievements and lessons learned over time while highlighting innovation in geotechnical engineering research and practice. The Local Organizing Committee for the conference invites

members from the Canadian and international communities to contribute papers and case studies dealing with historical design and construction practices or innovative analysis, techniques and solutions.

Authors are invited to submit their abstracts with a maximum of 400 words through the conference web site; *www.geovancouver2016.com*, which will be launched late September 2015.

The abstracts should generally fall within the following topics, but sessions will be added for groups of abstracts which share a common theme but are not listed below:

- Fundamentals

  Engineering Geology, Geomorphology, Soil Mechanics, Rock Mechanics, Physical and Numerical Modelling.
- Case Histories

  Site Characterization and Design of Tailings Dams, Slope Stability Analysis, Failure Analysis, Highway Improvement Projects, Seismic Design Aspects.
- Geohazards

  Climate Change, Floods, Landslides, Earthquakes, Tsunamis.
- Problematic Soils

  Soft and Compressible Soils, Expansive and Collapsible Soils, Loose and Liquefiable Soils, Residual Soils, Ground Improvement Methods, Geosynthetics.
- Infrastructure

  Bridges, Highways, Embankments, Dams, Pipelines, Tunnels, Shoreline Engineering, Harbours.
- Site Characterization

  Advanced Laboratory Testing, In Situ Testing, Instrumentation and Monitoring, GIS and Remote Sensing, Geophysical Methods.
- Foundation Design

  Spread Footings, Rafts, Driven Piles, Helical Piles, Caisson Piles, Retaining Walls, Soil Structure Interaction.
- Energy Resources

  Hydroelectric, Liquefied Natural Gas, Wind, Forestry, Mining, Tailings, Oil Sands.
- Design Codes

  NBCC 2015, CHBDC 2014.
- Groundwater & Hydrogeology

  Groundwater hydraulics, River Mechanics, Physical and Numerical Modelling.
- Cold Regions Engineering

  Ice Behaviour, Geocryology, Permafrost Degradation, Periglacial Processes.
- Geo-Environmental Engineering

  Landfills, Contaminated Soils, Contaminated Groundwater, Remediation.
- Education & Professional Practice

  Training and CV, Professional development, Communications, Contracts, Legal Aspects, Project Management.

The abstracts can be written in English or French. The deadline for abstract submission is January 29, 2016. Authors whose abstracts are accepted by the conference's Technical Subcommittee will be notified by February 26, 2016 and invited to submit full papers. The submitted papers, which can be in either English or French, will be reviewed prior to final acceptance and inclusion in the conference proceedings. At least one author of an accepted paper must register for the conference for its inclusion in the proceedings. Please address any questions to the Conference co-chairs: **Mustapha Zergoun** at *mzergoun@thurber.ca* or **Andrea Lougheed** at *alougheed@thurber.ca.*

69e conférence canadienne de géotechnique
2 - 5 octobre 2016
Vancouver, Colombie Britannique, Canada

Appel aux résumés

La Société géotechnique de Vancouver et la **Société canadienne de géotechnique** vous invitent à participer à GéoVancouver 2016; il s'agit de la 69e conférence canadienne de géotechnique. La conférence se déroulera du 2 au 5 octobre, 2016 à Vancouver, Colombie Britannique, Canada. Elle couvrira un large spectre de thèmes incluant des séances spéciales d'intérêt local et national dans les domaines de la géotechnique et géo-environmental. En plus du programme technique et des séances plénières, la conférence inclura des cours intensifs, des visites techniques, des excursions guidées et des activités sociales amusantes.

Les langues officielles de la conférence seront le français et l'anglais. Vancouver est bien connue pour sa beauté spectaculaire avec les montagnes côtières, le fleuve Fraser et le détroit de Georgia. La ville a été l'hôtesse de nombreux évènements nationaux et internationaux, incluant les Jeux Olympiques d'hiver en 2010. Cette région surprenante comprend une grande variété de conditions géologiques et de défis géotechniques tels qu'une sismicité élevée, des terrains accidentés et des sols mous. La Conférence se tiendra à l'Hôtel Westin Bayshore qui est bien situé entre le centre-ville d'affaires et le parc Stanley.

Le thème de GéoVancouver 2016 est **"Histoire et Innovation"** et il vise à reconnaitre les accomplissements historiques et les leçons apprises au fil du temps, tout en mettant en valeur l'innovation dans la recherche et la pratique de la géotechnique.

Le comité d'organisation de la conférence invite les membres des communautés canadienne et internationale à contribuer par des articles et des études de cas historiques, portant sur la conception, la construction ou l'analyse à partir de techniques et de solutions novatrices.

Les auteurs sont invités à soumettre des résumés de 400 mots au plus en utilisant le site de la conférence; *www.geovancouver2016.com* qui sera lancé à la fin septembre 2015. Les résumés devraient normalement se rattacher à l'un des thèmes suivants, qui pourront cependant être modifiés en fonction des résumés reçus.

- Aspects fondamentaux

  Géologie de l'ingénieur, géomorphologie, mécanique des sols, mécanique des roches, modélisation physique et numérique.

- Historique de cas

  Caractérisation et conception des digues de parcs à résidus miniers, stabilité des pentes, analyse à la rupture, projets d'autoroutes, aspects sismiques.

- Risques naturels

  Changements climatiques, inondations, glissements de terrain, séismes et tsunamis.

- Sols problématiques

  Sols mous et compressibles, sols susceptibles aux affaissements, sols gonflants, sols lâches et susceptibles à la liquéfaction, techniques d'amélioration des sols, géosynthétiques.

- Infrastructures

  Ponts, autoroutes, barrages en terre, pipelines, tunnels, génie côtier, ports.

- Charactérisation des sites

  Essais avancés en laboratoire, mesures in situ, instrumentation, Systèmes d'information (SIG) et télédétection, Méthodes Géophysiques

- Calcul de fondations

  Semelles, pieux battus, pieux à hélices, caissons, murs de soutènement, interactions sol-structure.

- Ressources énergétiques

  Hydroélecité, gas naturel liquéfié, éoliennes, génie forestier, génie minier, résidus miniers, sable bitumineux.

- Codes nationaux

  Code national du bâtiment 2015, Code canadien des ponts et chaussées 2014.

- Eaux souterraines et Hydrologie

  Hydraulique des eaux souterraines, mécanique des rivières, modélisation physique et numérique.

- Génie des régions froides

  Comportement de la glace, géocryologie, dégradation du pergélisol, processus périglaciaires.

- Géotechnique environmentale

  Dépotoirs, sols et eaux souterraines contaminés, restauration.

- Education et activités professionnelles

  Formation et CV, développement professionnel, communications, contrats, aspects légaux, administration de projets.

Les résumés peuvent être rédigés en français ou en anglais. La date limite pour soumettre un résumé est le 29 janvier 2016. Une invitation pour la soumission d'articles sera envoyée avant le 26 février 2016 aux auteurs dont les résumés auront été acceptés par le sous-comité du programme technique. Les articles soumis, en français ou en anglais, seront révisés avant leur acceptation pour publication sur clé USB dans les comptes rendus de la conférence. Au moins un des auteurs d'un article accepté doit s'inscrire à la conférence pour la publication de cet article. Vous pouvez acheminer toutes questions aux coprésidents de la conférence: **Mustapha Zergoun** à mzergoun@thurber.ca ou **Andrea Lougheed** à alougheed@thurber.ca.

International Short Course on Design and Assessment of Mine Waste Structures
December 10 to 15, 2015
Edmonton, Alberta

The University of Alberta Geotechnical Centre is pleased to host the First Circular International Short Course on Design and Assessment of Mine Waste Structures (Tailings Dams and Rock Dumps) in Edmonton, Alberta, December 10-15, 2015.

This five-day course will cover the design, construction, operation, monitoring, evaluation and safety of mine waste facilities. Lecturers include **Norbert R. Morgenstern**, **Dirk Van Zyl**, **Steve Vick**, **Andy Robertson**, **G. Ward Wilson** and other distinguished researchers and practitioners. For more information and/or to register, please contact **Sally Petaske** at *sally.petaske@ualberta.ca*

CYGEGC

Canadian Young Geotechnical Engineers & Geoscientists Conference

5th Canadian Young Geotechnical Engineers & Geoscientists Conference
September 29 to October 1, 2016
Whistler, British Columbia

The 5th Canadian Young Geotechnical Engineers & Geoscientists Conference is a triennial Canadian Geotechnical Society event. The conference is targeted towards young engineers and geoscientists who are looking to exchange technical information with their peers and build meaningful networks in a relaxed, supportive, and motivational environment. The conference will be hosted in Whistler, B.C from September 29th to October 1st, 2016, prior to GeoVancouver 2016. Participants are encouraged to submit abstracts and prepare short presentations. For more information go to *www.cygegc2016.com* or contact the

CGS Conference.

conference chair, **Julian McGreevy** at *chair@cygegc2016.com* .

A Look Back at GéoQuébec 2015 September 19 to 24, 2015 Quebec City, Quebec

La conférence **GéoQuébec 2015**, qui s'est tenue à Québec en septembre dernier, a été une réussite. Plus de 800 délégués ont participé à la Conférence. 380 présentations orales et 28 posters ont été présentés en plus des conférences de nos invités.

Le banquet et la croisière sur le fleuve St-Laurent ont été particulièrement appréciés. Ces activités ont permis aux délégués de passer de bons moments en compagnie de collègues et de faire de nouvelles rencontres dans un environnement décontracté.

La conférence s'est terminée par les visites techniques dans la région de Québec et de Charlevoix. En plus du volet technique, ces activités ont permis aux participants de visiter notre belle région et de déguster des produits du terroir québécois.

Musical gymnastics at CGS Awards Gala.

En terminant, nous vous remercions tous, chers collègues et amis, de votre participation à la Conférence.

GéoQuébec 2015, held in Québec City last September, was a success. More than 800 delegates participated to the conference. In addition to our guest speakers, 380 oral presentations and 28 posters were presented.

The Awards Gala Banquet and the Local Colour Night cruise on the St Lawrence River were particularly appreciated. Delegates had a good time chatting with colleagues and to meet new people in a relaxed environment.

The conference ended with technical tours in the Québec City and the Charlevoix area. Besides the technical aspect, these activities allowed participants to visit our beautiful region and enjoy local Quebec products.

Finally, we would like to thank you all, dear colleagues and friends, for your participation in the Conference.

Submitted by Jean Côté
Chair - GéoQuébec 2015

Heritage Committee

History of Local Chapters of the Canadian Geotechnical Society

The Heritage Committee believes that the history of the local chapters of the Canadian Geotechnical Society to be valuable part of the Society and its members. The CGS Heritage Committee would like to assemble if at all possible, a collection of historical summaries of all the chapters. Hopefully these stories will encourage other local chapters of the CGS to gather their archives and write their own history.

If you have any questions or have other historical information that you wish to share or know of any opportunities to acquire material that is at risk of being lost, please contact the Chair

Participants of the Boischatel Cave technical tour.

of the CGS Heritage Committee, **Dr. David Cruden, P.Eng**., at *dcruden@ualberta.ca*

History of the Canadian Foundation for Geotechnique: Part 1

The **Canadian Foundation for Geotechnique** (CFG) is a registered charitable organization which funds the awards, prizes and distinguished lectures of the Canadian Geotechnical Society (CGS), and supports other activities that recognize geotechnical excellence.

In this first article, we review the origins of the CFG and of the many awards and prizes it supports. We also attempt to recognize a number of individuals who have contributed to this initiative over the years, with apologies for any errors and omissions. The focus is on the two predecessor organizations of the CFG, namely the Canadian Geotechnical Fund (CGF) and Geo Contributions (GC). The period covered spans from 1965 to 2000.

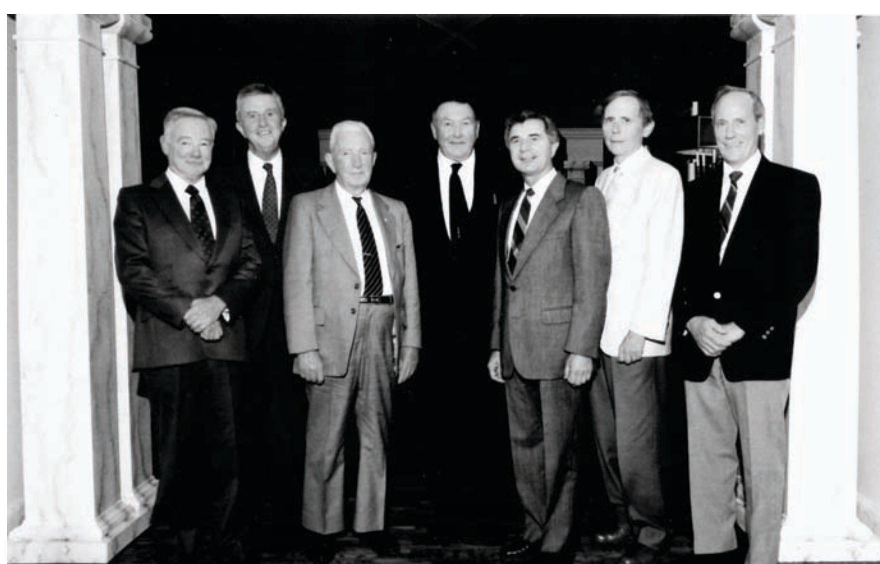
The Canadian Geotechnical Fund

In the 1960s, the Associate Committee on Geotechnical Research (ACGR) of the National Research Council of Canada (NRCC) acted as the Canadian National Committee of the International Society for Soil Mechanics and Foundation Engineering (ISSMFE).

In 1965, Canada hosted the Sixth International Conference on Soil Mechanics and Foundation Engineering in Montreal. **Dr. R.F. Legget**, then Director of the Division of Building Research of the NRCC and Chairman of the ACGR, was the Chair of the Organizing Committee for the Conference.

Following this landmark event, the ACGR recommended that profits from the conference and sales of the proceedings be deposited in a special trust account, and interest income from those deposits be used to promote and support geotechnical engineering and research in Canada. Out of this recommendation, which was endorsed by the NRCC and by **Dr. R.B. Peck**, then President the ISSMFE, the ACGR established the Canadian Geotechnical Fund (CGF) in September 1970.

A board of trustees was established to direct the investments, along with a subcommittee to advise on the use of the generated income, composed of



ACGR Chairmen and Technical Advisors honoured at a special dinner hosted by Golder Associates Ltd. on August 23, 1991, at the Rideau Club in Ottawa. From left to right, with years of ACGR involvement for each: Mr. C.B. Crawford (1966-76), Mr. V. Milligan (1983-88), Dr. R.F. Legget (1945-66), Mr. W.J. Eden (1951-85), Dr. M. Bozozuk (1985-91), Dr. D.H. Shields (1988-91), and Dr. L.W. Gold (1976-83; 1988).

one representative from the ACGR, one from the CGS, and the ACGR's Research Advisor. The initial signing officers of the CGF were **Mr. C.B. Crawford** (NRCC), and **Professor S.R. Sinclair** (University of Alberta).

Several of the ACGR chairmen and technical advisors from across the years are pictured below.

The ACGR managed the CGF from 1970 to 1989, during which time several projects were initiated with the goal of promoting and developing geotechnique in Canada. In 1970, in co-operation with the CGS, the **R.F. Legget Award** (for significant lifelong contributions to the geotechnical field) and the **Canadian Geotechnical Society Prize** (for the best paper published in the *Canadian Geotechnical Journal* during the preceding year) were established. Starting in 1973, recipients of both awards were also given an honorarium of $250 (increased to $500 in 1983).

In 1976, the CGF began funding travel costs for prominent Canadian or international geotechnical engineers to present two annual **Cross-Canada Lecture Tours** (CCLTs). The CCLTs had actually began in 1965, but until 1976 were funded by the ACGR.

The Canadian Geotechnical Colloquium was also established in 1976. It was awarded annually to a "young" engineer to present a paper on a selected topic at the annual CGS Conference, and included an honorarium of $2,500 as well as publication in the *Canadian Geotechnical Journal*. The CGF also participated in other initiatives, such as contributing to the publication of the book *Muskeg and the Northern Environment in Canada* in exchange for royalties from the University of Toronto Press, and contributing $1,500 to support a lecture by **Dr. A. Schofield** from Cambridge University at the CGS Conference in Vancouver.

Geo Contributions

In the late 1980s, the NRCC decided to phase out the ACGR, placing the CGF in danger of disappearing. In an attempt to preserve it, the CGF trustees decided to transfer the fund to the CGS, and in 1987, **Mr. A.G. Stermac** (Director General, CGS) successfully applied to federally incorporate the CGF's successor: Geo Contributions (GC). The following year, GC received tax-exempt status as a registered charity, under the condition that it was to operate at "arms length" from the CGS.

GC's first annual general meeting took place in 1989. The board of trustees and officers consisted of **Mr. J.L. Seychuk**, **Dr. M. Bozozuk**, **Dr. R.J. Mitchell**, **Mr. R.P. Northwood**, and **Ms. A. Poschmann**. As the years passed, the board expanded to 15 members who met annually in conjunction with the CGS conference.

In addition to the awards and programs previously supported by the Canadian Geotechnical Fund, Geo-Contributions established and funded several others, listed below.

- **R.F. Legget Award**; established by the CGS and the CGF in 1970 and described previously.
- **Canadian Geotechnical Society Prize**; established by the CGS in 1973 and described previously. In 1995 this prize was renamed the R.M. Quigley Award to honour the memory of this distinguished Canadian geotechnical and geoenvironmental engineer.
- **Cross Canada Lecture Tour**; established by the ACGR in 1965 and described previously. GC assumed funding the travel costs in 1976.
- **Canadian Geotechnical Colloquium**; established by the CGS in 1976 and described previously.
- **Thomas Roy Award**; established in 1982 by the Engineering Geology Division of the CGS.
- **Roger J.E. Brown Award**; established by the CGS in 1986 to honour the memory of this renowned Canadian Scientist in Permafrost.
- **R.M. Hardy Keynote Address**; established by the CGS 1987 to honour the memory of Dr. R.M. Hardy.
- **Undergraduate Student Report Awards**; established by the CGS in 1987 to recognize and reward excellence in the preparation of a geotechnical thesis by a full-time undergraduate student.
- **Graduate Student Presentation Award**; established by the CGS in 1988 to encourage geotechnical graduate students to prepare papers and presentations for the annual CGS Conferences.
- **G. Geoffrey Meyerhof Award**; established by the Soil Mechanics Division of the CGS in 1993 to honour the first President of the Canadian Geotechnical Society.
- **John A. Franklin Award**; established by the Rock Mechanics Division of the CGS in 1993, to honour the past President of the International Society for Rock Mechanics.
- **A.G. Stermac Award**; established by the CGS in 1999 to mark the retirement in 1998 of the former President and Director General of CGS, This award was previously called the CGS Service Plaques.

Throughout the 1990s, interest rates fell affecting earnings from investments, and GC financial resources consequently dwindled. GC trustees had to make many difficult decisions during those years, including eliminating the honoraria associated with several of the awards, and directing the savings towards supporting the two student awards. It also became necessary to cancel some of the Cross-Canada Lecture Tours.

By the late 1990s, concerned that other core activities might also have to be cancelled, GC established an investment committee (chaired by **Dr. R. Benson**) and a fund-raising committee (chaired by **Dr. J.I. Clark**) to seek corporate sponsorships and build up GC funds. Initial response was strong, with about $60,000 raised by 2000. The number of donors was small, however, and many people felt that the name "Geo-Contributions" should be changed to something that more obviously suggested the promotion of the geotechnical community.

The photo below shows the presidents of Geo Contributions from its inception in 1989 to 2000, when its name was changed to the Canadian Foundation for Geotechnique (CFG). In addition to these individuals, and to Drs. Benson and Clark, GC Officers who worked hard through this difficult period to continue to "recognize and foster excellence in the geotechnical field in Canada" included **Dr. K.T.Law** (Vice President, 2000), **Mr. R.P. Northwood** (Treasurer, 1989-1997), **Ms. E. Partsis** (Treasurer, 1998-2000), **Ms. A. S. Poschmann** (Secretary, 1989-1997) and **Mr. A.J. Walker** (Secretary, 1999-2000).

This is the first article of a two-part series. It is based on an article prepared by Dr. Michael Bozozuk and originally published in Geotechnical News in December 2007. The original article was edited by Drs. Heinrich Heinz and Dennis Becker to fit CGS News Publication requirements.

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Presidents of Geo-Contributions: Mr. J.L. Seychuk (1989-90), Dr. T.C. Kenny (1991-92), Mr. M. Devata (1993-98); Dr. M. Bozozuk (1999-2000).

2015 R.F. Legget Medal Award - le médaillé R.F. Legget 2015 Awarded to Jacques Locat

Serge Leroueil Introducing 2015 Legget Award Winner, Jacques Locat

Introduction of 2015 R.F. Legget Medal Winner by Professor Serge Leroueil - Université Laval

Jacques est un collègue depuis bientôt 35 ans, un proche collaborateur et un ami. C'est donc un immense plaisir pour moi de vous le présenter.

Jacques is a colleague, a close collaborator and a friend. It is thus a huge pleasure for me to introduce him.

Avec un baccalauréat en géologie de l'Université du Québec à Montréal, une maîtrise en quaternaire de l'Université de Waterloo, et un doctorat en géotechnique de l'Université de Sherbrooke, Jacques s'est donné les outils qui allaient façonner sa carrière, à cheval sur la géologie et la géotechnique.

His academic carrier started at Université Laval, in Quebec City in 1981, with his main research focus on soft sediments, submarine mass movements and their consequences. For example, he recently characterised the earthquake which struck the Province of Quebec in 1663, on the basis of landslides that occurred at that time.

Ses principales recherches ont porté sur les sédiments récents et sur les mouvements de terrain et leurs conséquences. Dans ses travaux, il a toujours su mettre en œuvre les dernières technologies, ce qui nous a valu, entre autres, de magnifiques photos d'argiles au microscope à balayage et d'images de fonds marins.

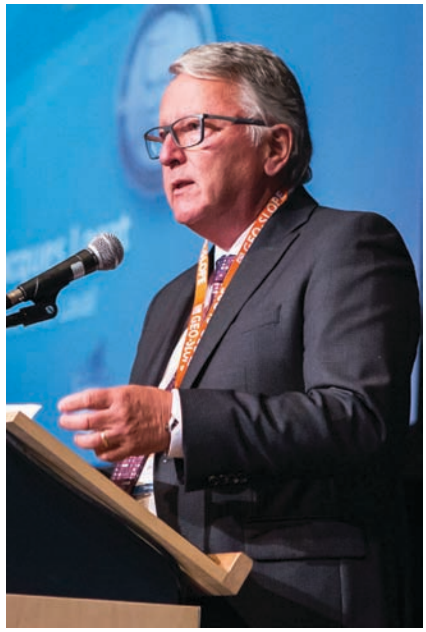
In addition, Jacques is a real leader in the profession. In 2003, he initiated a series of conferences focusing on submarine landslides and their consequences, which are now held every two years. They remain the main gathering of people involved in this field. He has also co-organized several other national and international conferences.

Son leadership a aussi amené Jacques à être président du Comité international sur les glissements de terrain de 1997 à 2001, Vice-président pour l'Amérique du nord de l'Association des ingénieurs géologues de 2002 à 2006, et Directeur du programme international de coopération géoscientifique sur les glissements sous-marins de l'UNESCO de 2005 à 2009. Ses travaux et son implication sont bien connus et reconnus aux niveaux national et international.

Jacques has been recognized both nationally and internationally. He became **Fellow of the Engineering Institute of Canada** in 1997, won the K.Y. Lo Medal in 2005 for his contributions at the international level, was invited to deliver the **22nd Bjerrum Lecture** in 2009, and obtained the **Schuster Medal** jointly from the Canadian Geotechnical Society and the American Association of Environmental & Engineering Geologists in 2013.

Jacques a aussi de grandes qualités humaines : il est sympathique, très généreux, et apprécie partager un bon repas avec des amis. Son parcours est apprécié même à l'intérieur de sa famille puisque son neveu Pascal et sa fille Ariane ont décidé de faire carrière dans le même domaine que lui.

So, combining his great human qualities, important research contributions and strong involvement in the profession at both the national and international levels, Jacques is clearly a worthy recipient of the Legget Medal. Congratulations Jacques! Félicitations mon ami!



Jacques Locat, 21 septembre 2015.

2015 R.F. Legget Medal Award Acceptance Speech Professor Jacques Locat - Université Laval

Je voudrais d'abord remercier les personnes qui ont pris l'initiative de proposer ma candidature (il faut croire que j'ai encore beaucoup d'amis) ainsi que le Comité de nomination pour m'accorder cette reconnaissance pour le travail que j'ai accompli et qui le fut avec grand plaisir et cela grâce à la contribution du plusieurs personnes, particulièrement celle de ma famille: Ghyslaine, mon épouse et mes filles Virginie et Ariane.

Looking at this award and medal, I remember the few times that I had the privilege to meet with Dr. Legget at earlier CGS conferences. He also was very much interested by the field of Engineering Geology, as shown by his book on Cities and Geology published in 1973. Dr. Legget was also the founder of the first Canadian Permafrost Conference in 1962, so, for me, receiving this award at the time when both the Canadian Geotechnical Society and the Canadian National Committee for the International Permafrost Association are meeting is an interesting coincidence that I appreciate.

Les premières personnes qui m'ont entraîné dans le domaine de la géologie de l'ingénieur lors de mes travaux d'été au baccalauréat sont Denis St-Onge et Alan Heginbottom de la CGC et Jean-Yves Chagnon alors avec le Ministère des richesses naturelles du Québec. Pour un géologue de l'UQAM, ma carrière était donc bien lancée avec autant de professionnels et chercheurs passionnés dans le domaine de la géologie de l'ingénieur qui m'ont donné le goût pour la recherche.

Au cours de mes études graduées, j'ai eu la chance d'avoir des mentors très généreux de leur temps et de leurs connaissances.

From 1974 to 1976, for my Master thesis at the University of Waterloo, I studied Quaternary geology and geomorphology with Paul Karrow, Owen White and John Cherry. Later, in 1976 and 1977 at the University of Alberta, I began my PhD by learning about rock mechanics and studying mass movement in the Rockies under the supervision of Dave Cruden. I had the time to also appreciate his particular sense of humor. At U of A, I also had the chance to have frequent weekly late Friday afternoon talks with Professor Morgenstern on all kinds of topics while on my way back to the apartment!

En 1977, pour diverses raisons, j'ai rejoint Guy Lefebvre à l'Université de Sherbrooke pour y faire mon doctorat en mécanique des sols au département de génie civil. De Guy je retiens sa passion pour comprendre le comportement des sols, mais aussi l'importance du terrain dans le développement des connaissances, ainsi que le lien pour un ingénieur entre la recherche à la pratique (e.g. construction de digues, glissements de terrain). J'ai réalisé mon doctorat à Sherbrooke avec un 'co-chambreur' de laboratoire et excellent ingénieur et ami, Alain Philibert, qui est malheureusement décédé trop jeune cet été.

En 1981, avec un parcours gradué prolongé mais comprenant un bagage de mécanique des roches et de mécanique des sols en poche je suis arrivé à l'Université Laval où j'y ai retrouvé Jean-Yves Chagnon. Jean-Yves m'a tout de suite généreusement allié à ses projets sur les glissements de terrain et la séismicité au Québec, deux thèmes que je chéris toujours! Par le fait même il m'a fait découvrir Charlevoix où nous avons le bonheur d'y avoir un petit retranchement! En hydrogéologie, quel plaisir j'ai eu à travailler avec Pierre Gélinas et Denis Isabel sur divers projets dont certains m'ont fait connaître l'Afrique. J'ai eu aussi plusieurs projets avec Marc-André Bérubé sur les granulats et les argiles. Je l'avais convaincu de commencer à regarder le béton, il n'a pas cessé depuis!

At the same time we developed an aggregate inventory method in Québec with the help Doug Vandine.

In 1984, I had an opportunity to go on a cruise on the Saguenay Fjord with Charles Schafer of the Geological Survey of Canada (GSC). What a fascinating environment and laboratory I discovered. Since then, we have used all kinds of scientific opportunities to help improve our understanding on how sediment develop, evolve and react to various conditions including earthquakes. This was to trigger of my long and lasting interest for submarine mass movements and their consequences.

Serge Leroueil et moi avons réalisé notre première expédition de géotechnique marine en 1985 au fjord du Saguenay, oui, il y a déjà 30 ans de cela! Pour vous donner un exemple à quel point nous étions des novices, nous avions prévu utiliser une balance pour faire des teneurs en eau sur le navire. Nous avons vite réalisé que cela était impossible sur un bateau et je revoie encore Serge sur le quai, avec une rallonge électrique venant du bateau et en train de peser des échantillons à minuit!

Mettre en place des projets importants comme le projet ADFEX (Arctic Delta Failure Experiment, 1989-1991), Saguenay post-déluge (1997-2002), et COSTA-Canada (Continental Slope STAbility, coopération avec l'Europe, 1998-2003) auraient été impossibles sans l'appui de plusieurs chercheurs canadiens, mais aussi de deux excellents chercheurs et amis : Jean-Marie Konrad et Serge Leroueil. Ils m'ont aussi appuyé à plusieurs reprises pour la direction des étudiants gradués. Serge et Jean-Marie sont deux perfectionnistes en leur genre et qui aiment les discussions animées (Jean-Marie en particulier!), mais surtout, ils sont des épicuriens qui apprécient les bons moments, et il y en a eu plusieurs!

Il y a naturellement Ariane, récente collaboratrice avec Serge et Jean-Marie et Guy Doré. Elle a déjà des plans pour ma retraite car elle voudrait m'avoir comme assistant bénévole dans son laboratoire!

Still, these projects and others involved many colleagues from across and outside of Canada and I would like to take this opportunity to acknowledge some of them for their great collaborations. At the Geological Survey of Canada, Jim Syvitski; Charles Schafer particularly for the ADFEX project At the Norwegian Geotechnical Institute, Harald Norem for ADFEX, Suzanne Lacasse, Farouk Nadim and Jean Sébastien L'Heureux for their continued collaboration on quick clays and risk. At the Laboratoire des Ponts et Chaussées in Aix-en-Provence, Gérard Colas. At the USGS, Homa Lee. At the Port and Harbour Research Institute (PHRI) with Hiroyuki Tanaka et à Rimouski avec Guillaume Saint-Onge, au Centre d'études nordiques avec Patrick Lajeunesse, et à l'Université de Lausanne avec Michel Jaboyedoff. Ce sont maintenant tous des amis! L'appui de mes collègues du Département de géologie et de génie géologique à Laval a aussi été essentiel à la réalisation de ces divers projets et d'autres.

I have had a long acquaintance with Homa Lee with whom I shared so many cruises and who very generously opened so many doors for me in the USA in the field of submarine landslides. The same is true with Hiroyuki Tanaka, who provided me with many opportunities to work with Japanese researchers on the geotechnical behavior of Japanese clays.

I had also learned a lot and enjoyed serving on projects like Ormen Lange in Norway, Rio Tinto in Wabush (Labrador) and recently on the Prince Rupert Gas Transmission project with BGC in Vancouver.

Notre recherche a toujours impliqué d'importants travaux de terrain et cela pour une meilleure formation de nos étudiants. C'est une bonne façon de connaître les étudiants et les collègues.

There is nothing like a two week ship expedition (not a cruise) on the Mediterranean Sea, the Gulf of St. Lawrence, the Saguenay Fjord or on the Pacific Ocean off California to really know your students and colleagues, particularly when they wake up in the morning.

Au cours de telles expéditions nous tentons d'y amener le plus grand nombre possible d'étudiantes et étudiants et plusieurs dans cette salle y ont vécu des expériences enrichissantes : Didier Perret, Denis Demers, Priscilla Desgagnés, Hélène Tremblay, Luc Boisvert, Christiane Levesque, Geneviève Cauchon-Voyer, Suen Won Jeong, Marie-Claude Lévesque et j'en passe. Ceci me permet de souligner que ce sont nos étudiants gradués et nos professionnels de recherche qui nous donnent la capacité d'atteindre nos objectifs.

Nos travaux récents nous ont ramené sur terre avec le projet Gascon et le projet Parachute rendus possible grâce à la participation de Catherine Cloutier, François Noël et Mélanie Mayers, ainsi que le projet Black Lake où on étudie le potentiel tsunamigénique d'un glissement actif avec Dominique Turmel et Jonathan Leblanc.

J'ai toujours dit qu'il n'y a pas de problème de financement pour la recherche au Canada mais que le vrai problème est d'attirer les bons étudiants et je pense que nous avons bien réussi. En plus, la collaboration se continue toujours avec eux même après leurs études et je pense ici à Réjean Couture, Didier Perret, Pascal Locat, Denis Demers, Catherine Cloutier, Dominique Turmel.

Having gone through the list of past Legget medalists I feel I am joining this club with some apprehension since it bears greater responsibilities. A common point for many of them is that they also served the community in various ways. In 1992, I had the privilege to serve as the President of the Canadian Geoscience Council (now the Canadian Federation of Earth Sciences) and it was a great opportunity to develop a large network across various earth science disciplines. For young students, scientists or engineers, I strongly recommend that you get involved in your respective learned society on committees or in the organizing of conferences like this one, or something else… embarquez!

En résumé, voici mes ingrédients favoris : la curiosité, la générosité, une écoute aux préoccupations des partenaires gouvernementaux, institutionnels et industriels, et une implication dans le milieu. Le tout dans un climat qui se doit d'être harmonieux et agréable.

L'avenir m'attend avec d'autres défis, différents peut-être. Prévoir le futur est une mission difficile, mais quand je regarde le passé, je suis toujours étonné des divers projets excitants que nous avons pu réaliser et des merveilleuses personnes que j'ai connues. Alors si le passé est garant du futur je souhaite que cela demeure et qu'ainsi le futur s'accorde avec le passé!

Merci beaucoup.

L to R – Serge Leroueil, Dennis Becker, Jacques Locat, Doug Vandine.

Introduction by John Dunnicliff, Editor

This is the 84th episode of GIN.

Three articles this time.

Specifications for robotic total station field work

I've written several of these, and now realize how flawed they were. I see similar wording being used in new specs, and we need to do all that we can to stop this practice.

The first article by Douglas Roy and Jonathan Stuhl makes this clear, and advises on contract specification language (from a North American perspective) for robotic total station (RTS) field personnel. These field personnel effectively run these systems and manage the data they create. The first author is a geotechnical professional engineer, the second a professional land surveyor, so we must regard their recommendations as from the two disciplines – i.e. don't regard this as a one-sided argument by geotechs.

Although this article should be of interest to professionals involved in RTS technology and usage, **it is particularly intended to guide owners, engineers and specification writers** tasked with the preparation of specifications on projects where RTS technology will be utilized. Those in bold font will generally not be readers of GIN, so the authors and I need your help to pass the recommendations on to the target audience. If you're in professional contact with any of those in bold font, will you please ask the Managing Editor of this magazine, Lynn Pugh, (*gn@geotechnicalnews.com*), cc to me (*john@dunnicliff.eclipse.co.uk)* to send you a pdf of the article, and then share it. We need to break the habit of copying and pasting from the flawed specs.

Please share this article with owners, engineers and specification writers involved with RTS technology – we need to break a habit

Knowns and unknowns

In my June 2012 introduction to GIN I highlighted the concept of known knowns, known unknowns, and unknown unknowns, and attributed the quote to ex-US Secretary of Defense Donald Rumsfeld. Don Shields contacted me to say that he was "ticked off" by this, believing that the concept of different degrees of unknowns is original to Elio D'Appolonia ("D'App").

Don then sent me the following article, entitled "Giving credit where credit is due". For those of you who don't know Don: a graduation thesis on the swelling pressures of Saskatchewan clays led him to a career in geotechnical engineering. His career combined consulting, teaching and research - with a special interest in insitu testing and foundations. He retired in 2000 as Dean of Engineering at the University of Manitoba.

General role of instrumentation, and summaries of instruments that can be considered for helping to provide answers to possible geotechnical questions.

The last of the three articles is an attempt identify:

- The general role of instrumentation for internally and externally braced excavations.
- The possible geotechnical questions that may arise during design or construction, and that lead to the use of instrumentation
- Some instruments that can be considered for helping to provide answers to those questions.

Similar suggestions for other project types will be in subsequent episodes of GIN.

Third International Course on Geotechnical and Structural Monitoring - June 2016 - Italy

The third international course on geotechnical and structural monitoring (www.geotechnicalmonitoring.com) will be held in Tuscany, Italy on June 7-9, 2016, followed by a field trip on June 10 to the Poggio Baldi landslide monitoring site (*www.landslidemonitoring.com)*.

To enhance the content on recent innovations, we're going to have three sessions in which registrants and exhibitors make professional presentations about new trends. In each of these sessions, four invited speakers will make brief presentations on new trends on each of the following:

- Contact monitoring
- Remote monitoring
- Data acquisition and management systems.

We also plan on two sessions in which about ten users will make ten minute presentations on case histories and lessons learned. Speakers will be selected based on an open call. **If you're interested in presenting during these sessions, please send an abstract of your proposed topic to the course organizer, Paolo Mazzanti, *paolo.mazzanti@nhazca.com.***

Correction methods for inclinometer errors

This subject remains obscure to most users. Manufacturers of inclinometers


Exhibitors' room


Lecture room


Street party


2015 Participants


Field Trip

3rd INTERNATIONAL COURSE ON GEOTECHNICAL AND STRUCTURAL MONITORING

June 7-9, 2016 Poppi, Tuscany (Italy)

Course Director: John Dunnicliff, Consulting Engineer
Organizer: Paolo Mazzanti, NHAZCA S.r.l.

THE COURSE: **attendance at the course is a great opportunity to establish a valuable network with colleagues from all over the world, to meet manufacturers and see the most recent and innovative instrumentation, thanks to a large exhibition area.**

NEW CONTENT: **to enhance the content on recent innovations, there will be three sessions of professional presentations about new trends in contact monitoring, remote monitoring, data acquisition and management systems. There will also be two sessions in which users will make brief presentations on case histories and lessons learned. If you're interested in presenting during these two sessions, please send an abstract of your proposed topic to: info@geotechnicalmonitoring.com.**

COURSE EMPHASIS: **the course will include planning monitoring programs, hardware and software, web-based and wireless monitoring, remote methods for monitoring deformation, vibration monitoring and offshore monitoring. Case histories will be presented by prominent international experts.**

WHO: **engineers, geologists and technicians who are involved with performance monitoring of geotechnical features of civil engineering, mining and oil and gas projects. Project managers and other decision makers who are concerned with management of RISK during construction.**

LOCATION: **the 3-day course will be held in Poppi, Tuscany (Italy). In addition to providing an opportunity to increase your own technical expertise, you will have a cultural and historical experience in one of the most attractive places in the world.**

FIELD TRIP: **an optional Field Trip will be held, at the end of the Course (10th June), on a large landslide site, where practical demonstrations of monitoring equipment will be performed by international leading Partners.**

Course Partners: **Measurand, Canary Systems, Geokon, Sylex, 3D Laser Mapping, Vista Data Vision, Soldata, Geosense, GKM Consultants, Marmota Engineering, Campbell Scientific, CSG - Centro Servizi di Geoingegneria, Smartec, Metasensing, Bartec Syscom, IDS Ingegneria Dei Sistemi. (Updated October 2015)**

www.geotechnicalmonitoring.com

don't emphasize that there is potential for systematic errors in inclinometer results. Diagnostic plots and correction routines are built into DigiPro 2 – Advanced (*www.slopeindicator.com*) and GTilt (*www.mitresoftware.com*) software, but not others as far as I know, but users can get guidance from Slope Indicator's website *www.slopeindicator.com/index.php*.

Erik Mikkelsen wrote a paper for the 2003 Symposium on Field Measurements in Geomechanics, (FMGM) in Oslo, Norway, titled "*Advances in inclinometer data analysis*", in which he described the major errors and provided guidance in error correction. Together with Elmo DiBiagio, Erik wrote a second paper for the 2015 FMGM in Sydney, Australia, titled "*Depth position errors in inclinometer surveys and false displacement results*", elaborating on part of the 2003 paper.

Because FMGM papers are not as readily accessible as articles in GIN, Erik had agreed to write three articles for GIN:

1. Calibration errors: Bias and sensitivity shifts
2. Rotation errors due to probe azimuth shifts and casing cross-axis inclination
3. Depth positioning errors and influence of casing curvatures

The plan is to publish these articles in the next three episodes of GIN.

Procedings of the ninth FMGM

The proceedings of the ninth International Symposium on Field Measurements in Geomechanics (FMGM), held in Sudney, Australia on September 9-11, 2015 are now available. The bound proceedings (829 pages) contain 65 papers, divided into the following subject areas:

- Case studies
- Civil tunneling
- Water flow and monitoring
- Underground mining
- Transport corridors
- Coal mining and associated excavations
- Carbon sequestration
- Slope stability

The proceedings include a stage-setting presentation by Philip Pells, titled ''Monitoring - the good, the bad and the ugly''.

The proceedings can be ordered at www.acg.uwa/edu.au/shop - scroll to ''FMGM 2015''. The cost is Australian $220, US$170, including courier delivery.

Mea culpa

In the previous GIN I wrote, "The rugby world cup will be played here in England during September and October. Yes, USA will be competing, but not Canada". I was wrong! Soon after we went to press I realized that Canada **was** playing, and expected a blast of complaints from readers. But only one! This seems to mean that:

- Only one Canadian reads my stuff, or
- Canadian readers don't care about rugby, or
- Canadians are uncomplaining and forgiving.

Now to the single blast:

> "I strongly resent your assertion that Canada is not good enough to go to the Rugby World Cup however, the USA is good enough. Maybe I should not believe your opinions on instrumentation either! A humble retraction in the next Geotechnical News is warranted."

Wow! We made peace, and I learned that it was 'tongue in cheek'!

Finlay Currie as Abel Magwitch in Great Expectations*, 1946.*

A tale to tell

Did you read Charles Dickens' classic novel *Great Expectations*? Or see the original 1946 movie or the 2012 re-make? A primary character is Abel Magwitch, an escaped convict. I recently spent some ouchy days in a hospital with a fractured hip, and on the second day 1946 Magwitch (same frightening face and same heavy physique) was wheeled to the adjacent bed space. Handcuffed to the bed, with two policemen, one of whom was also handcuffed to the bed, presumably to prevent rescue by his buddies by taking patient and bed! He'd broken a knee and arm while playing soccer in the nearby high-security prison in the Dartmoor National Park (I live in the Park). He and his guards were very noisy, even after the lights went out, and I was relieved to be moved to a different room the next day. But the following day he reappeared alongside me, again with the noise! And can you believe this? – the two moves were repeated two days later! Not what I needed, but the UK National Health Service was superb.

Closure

Please send an abstract of an article for GIN to *john@dunnicliff.eclipse.co.uk* —see the guidelines on www.geotechnicalnews.com/instrumentation_news.php

Stin ijiasas (Greece). Make a toast to their future – they need you to do that.

Qualifications of the robotic total station construction monitoring professional

Douglas Roy and Jonathan Stuhl

Introduction

The use of robotic total stations (RTS), also referred to as automated motorized total stations (AMTS), has become more and more prevalent in modern construction related monitoring programs. This increase comes from realization by practitioners to the cost and efficiency benefits over manually survey monitoring as well as through contract specifications from owners and engineers to provide tighter tolerances and quicker response times. With the gap closing (or widening) between North American Professional Land Surveyors and Professional Engineers regarding the use of RTS units, questions arise as the necessary background and experience required for practitioners to effectively design, as well as run these systems and manage the data they create. Although this article should be of interest to all professionals involved in RTS technology and usage, it is particularly intended to guide owners, engineers and specification writers tasked with the preparation of specifications on projects where RTS technology will be utilized.

RTS for construction monitoring

In the early twenty-first century the improvements in telecommunications along with integration of robotics into the total station brought about the possibility of using these RTS units for remote monitoring. A total station that normally required a survey technician or transit man to run could now be controlled remotely and data sent to a remote location for plotting and analysis. With hardline communication and power connections an RTS unit could be installed in a location possibly inaccessible to a survey crew and no longer require untimely access in order to provide 3D survey monitoring information, see Figure 1. In addition to the access issues this system overcame, it introduced a level of high accuracy/ high volume measurements not previously available. Measurement cycles were completed and data returned for review within short minutes and the process completed electronically heavily limiting the human error side of survey monitoring. Continuous changes in technology have led to the wireless alternative of the RTS where a wireless cellular modem is used to maintain communications and solar panels are used to power the system.

As the technology of RTS has become more accessible the use of the instruments in monitoring for construction large and small has increased. When initially introduced the cost of these systems was prohibitive to the point that only large scale "mega" projects could find the improvement outweighing the cost. Today the RTS monitoring solution is prolific in many construction venues from tunnels and bridges to high rise sky scrapers and dams to even residential construction in urban environments.

Recent contract specification requirements

As the value of RTS monitoring was evident and the desire for increased monitoring data found appeal with owners and engineers, some modifications to contract specifications were expected. Specifications regarding frequency of measurements and expectations of data delivery timelines were updated. No longer was there a one day turn around for a survey crew to complete field measurements, return

Figure 1. Typical RTS installation.

to an office environment and complete calculations and produce deformation results. Now the process was specified to be more streamlined and provide same day turn around and include forms of automated notification to stakeholders of deformations above limits.

In order to assure that quality data were to be provided per specification the language was changed to incorporate RTS measurements with other geotechnical monitoring data under what is often referred to as the Geotechnical Instrumentation Engineer (GIE). This engineer, typically required to be a Professional Engineer in the state/province that the work is undertaken is specified to have many years of experience with the installation, use and interpretation of data from all of the monitoring instruments to be installed per the contract including the RTS. Beyond this general qualification for the GIE there is little requirement for the experience of technicians or the GIE for reduction of RTS data for use in deformation monitoring as it relates to the statistical or realistic reliability of the monitoring data. There have been a small number of specifications that include a requirement for an AMTS (RTS) Specialist. These specifications generally require that this position be filled by a person with two to three years of experience with and having successfully completed some number of similar projects involving RTS monitoring.

Relevant experience for practitioners

The practice of land surveying is often defined by 50 United State and one district boards and similarly in the remainder of North America as that practice which includes special knowledge and application of mathematics to measuring, plotting and layout of dimensions, areas and volumes on and above the earth or of/on man-made structures. It also includes the location, layout, measurement of the lengths and directions of boundary lines (property lines), monumentation thereof and the application of legal rules and regulations for legal descriptions and conveyance of real property. The Professional Land Surveyor (PLS) is entrusted with taking measurements of the earth and structures and applying mathematical and regulatory principals to determine positions and elevations.

Figure 2. Prisms monitoring large crack in a building.

Professional Engineering is often defined by 50 United State boards and similarly in the remainder of North America as that practice which includes the planning, designing, composing, evaluating, advising, reporting, directing or supervising that requires the application of engineering principles which concerns the safeguarding of life, health, property, economic interests, the public welfare or the environment, see Figure 2.

Professional Engineers (PEs) work to guarantee the public's safety and promote its interest where engineering matters are concerned. They must also ensure that provincial laws adequately and properly serve and protect the public, and participate in the establishment and maintenance of engineering standards while adhering to a code of ethics.

Now every state and province regulates the practice of engineering to ensure public safety by granting only PEs the authority to sign and seal engineering plans and offer their services to the public.

PEs are defined by various disciplines, (Civil, Structural, Mechanical, Electrical, Nuclear, etc.) by various state and provincial boards, typically with different testing and experience requirements. Often the state and provincial boards for both PEs and PLSs are under the same administrative arm. Important to this discussion is that PE and PLS standards of care require that they shall only undertake assignments when qualified by education or experience in the specific technical fields involved.

This goes to the heart of this discussion. Is a Professional Engineer, licensed in the state/province where work is being performed, or any other state/providence for that matter, qualified to administer a RTS program? To answer that lets first discuss the process of the design and implementa-

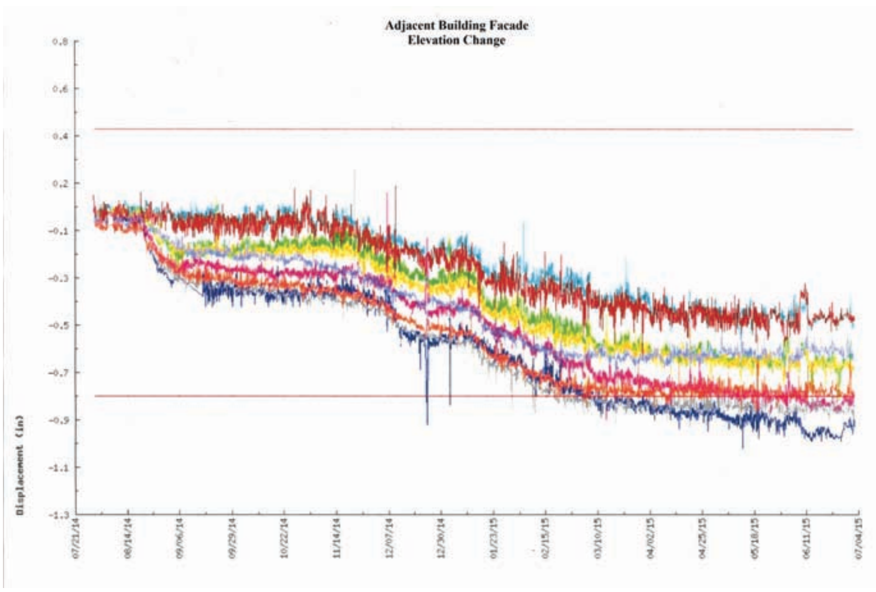


Figure 3. Long term monitoring data from a RTS system showing settlement of a building façade.

tion of a RTS program based on five distinct steps.

- Design the layout of RTS locations to maintain stability, reduce environmental errors and incorporate sufficient stable control to evaluate movement of the RTS and may also include the design of the specific locations to be monitored
- Proceed with the installation and testing of the system to verify functionality and adherence to designed criteria for accuracy and precision
- Data processing is setup to compile and reduce the measurements using appropriate methods of calculation
- Review of the data for quality assurance and identification of movements and trends as well as properly identifying possible data spikes due to transient factors, see Figure 3.
- Use information from the data review to refine and adjust the processing model as needed for changed conditions in the control reference frame or environmental factors.

The direct measurement, taken with a RTS would be the same whether programed by a PLS or PE. Much different then in previous generations where each measurement was made in the field by a two man survey crew, one of which was often the PLS.

Where the Professional (Professional Engineer or Professional Land Surveyor) is needed involves how this resulting measurement is processed, refined and used within an instrumentation data base. Given the advancements in data processing and database manipulations that are undertaken using the least square programs (see Figure 4), the initial phases of data base processing of the direct survey data are more akin to that a professional mathematician or computer software engineer. But key to the Professionals input is the installed RTS location(s) and layout to the reflective monitoring points, confirming that the measurements between these two points will give the best quality data, how corrections to data is undertaken to correct for various error types, and of most important how to address trends or direct movement of points. In this evaluation the Professional must also consider the structure being monitored, its ambient movement as a result of thermal expansion, the impact of the movement to the structure and some of the reasons that movement may be occurring, such as the excavation or tunnel construction.

RTS construction monitoring does not include the definition and layout of boundary lines (property lines), nor the legal description and conveyance of real property. Whereas it does include the use of highly precise instruments for the measurements of

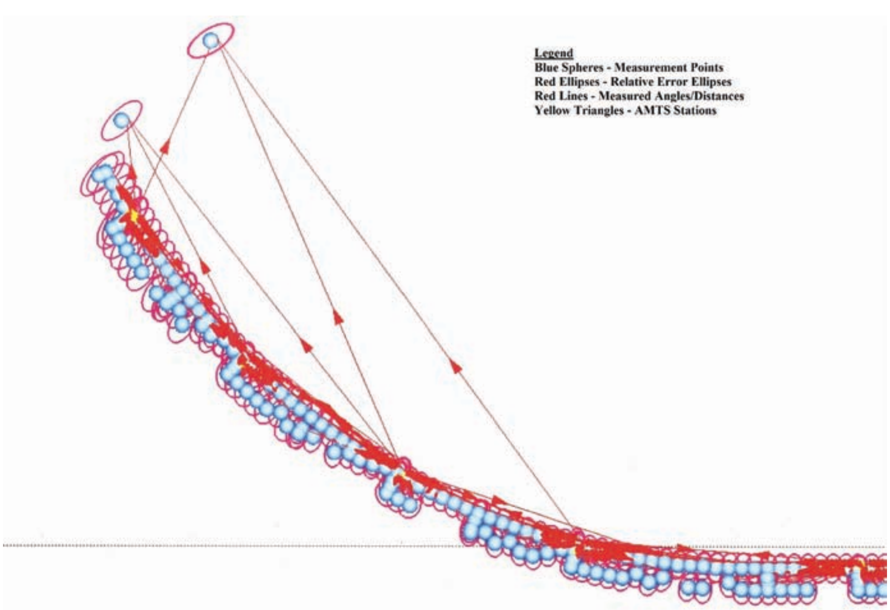


Figure 4. Least squares adjustment plot showing relative error ellipses.

the earth and structures and applying mathematical and regulatory principals to determine positions and elevations of points on structures or the ground surface where the change in position of such points are a concern for safeguarding of life, health, property, economic interests, the public welfare or the environment.

Clearly both the PE and PLS standard of conduct requires that the Professional only undertake assignments when qualified by education or experience in the specific technical fields. The difficulty in the RTS implementation is that neither a PLS nor PE is formally trained on all these issues. On projects without formal specification, the Professional typically decides if he or she has the qualifications required to perform the work.

Until such time that the relatively new field of RTS monitoring advances to influence the state or provincial registration boards, this "mix" of Professionals involved in RTS construction monitoring will likely continue.

It is these writers' opinion that both a PE and PLS can be qualified to undertake a RTS program, and that other degrees and experience may also qualify. The argument of who should be qualified as the GIE, will not be debated here.

Recommendations for contract specification language

The frustration with RTS program specifications has been prevalent in the North American industry for more than a decade, and discussed well in the September 2009 GIN article by Dail and Volterra.

It is these authors' recommendation, as representatives for both PEs and PLSs that the need for a separate AMTS (RTS) specialist is well suited and generally the best for the project, especially in the cases where there is a large amount of "in ground" instrumentation being addressed by the GIE.

We would anticipate that such a specification would generally outline as follows:

Robotic Total Station (RTS) Specialist who shall have previous experience in installation, monitoring, and data interpretation of at least two RTS systems in applications similar to those specified herein. The RTS Specialist shall perform the following tasks:

- Design and detail the overall configuration and appurtenant hardware and installation procedures for the entire RTS system, including final locations of the components.
- Perform pre-installation and post-installation acceptance tests and supervise installation of the system in its entirety.
- Collect, reduce, process and plot RTS data.
- Review RTS system data for quality assurance, identification of erroneous data and identification of movement trends.
- Incorporate information from data review, changed site conditions and/or unanticipated changes to system design into the RTS system processing model.
- Be a PE or PLS in the state or province where the project is located

We hope to see additional attention paid to the details and qualifications of this specialty as the use of RTS monitoring continues to grow.

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Emily B. Dail, and Joel L. Volterra, "Instrumentation and Monitoring Trends in New York City and Beyond", Geotechnical News, September 2009. www.geotechnicalnews.com/pdf/GeoTech-News/2009/GIN%202703.pdf

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Giving credit where credit is due

Donald Shields

I am at the age when finding myself in the kitchen I have to stop and ask myself "Why did I come here? What am I looking for?" Also at the age that things 'tick me off' probably more frequently than they used to.

I was ticked off three years ago when I read Geotechnical Instrumentation News [GIN] give credit to ex-US Secretary of Defense Donald Rumsfeld. The mention of Rumsfeld's name, usually in association with Dick Cheney, ex-US Vice President, makes me grit my teeth, I admit.

The introduction to June 2012 GIN highlighted the concept of Known knowns, Known unknowns, and Unknown unknowns. These are risk management terms that apply, for example, in resource development when the long term environmental hazards of development are being considered. It is not possible to imagine today all of the issues that might manifest themselves say 10 or 100 years from now. Hence the concept of Unknown unknowns.

The GIN introduction seemed to imply that the concept originated with Rumsfeld at the U.S. Department of Defense news briefing he gave on February 12, 2002. The subject at hand was the lack of evidence linking the government of Iraq with the supply of weapons of mass destruction to terrorist groups.

In spite of my inability to remember why I am in the kitchen, the synapsis of longer term memory fired on reading the introduction. I remembered the moment in 1979 when Elio D'Appolonia used the words Unknown knowns and Unknown unknowns. The reason I remember was I said to myself "Why didn't I think of that?" That is now 36 years ago.

The occasion was the presentation by Dr. Elio D'Appolonia at the Province of British Columbia Royal Commission of Inquiry into Uranium Mining (1). With respect to the design and construction of uranium tailings impoundments, Dr. D'Appolonia testified:

Site conditions always pose unknowns, or uncertainties, which may become known during construction or operation to the detriment of the facility and possibly lead to damage of the environment or endanger public health and safety. The risk posed by unknowns is somewhat dependent on the nature of the unknown relative to past experience. This has led me to classify unknowns into one of the following two types: 1. known unknowns (expected or foreseeable conditions), which can be reasonably anticipated

Dr. Elio D'Appolonia in 2008.

but not quantified based on past experience as exemplified by case histories in Appendix A, and 2. Unknown unknowns (unexpected or unforeseeable conditions), which pose a potentially greater risk simply because they cannot be anticipated based on past experience or investigation.

Known unknowns result from phenomena which are recognized, but poorly understood. On the other hand, unknown unknowns are phenomena which cannot be expected because there has been no prior experience or theoretical basis for expecting the phenomena.[1]

The concept of different degrees of unknowns is original to D'Appolonia I believe. As the above testifies, the concept certainly did not originate with Rumsfeld. Rumsfeld's presentation was 23 years after Elio D'Appolonia made his remarks.

The Royal Commission of Inquiry into Uranium Mining was set up in response to development work that was being carried out for the proposed Blizzard uranium mine near Kelowna, BC. British Columbia has nearly two hundred known mineral occurrences of uranium. In spite of these mineral riches, there had never been an operating uranium mine in the province.

I was one of a team of consulting engineers working on the Blizzard site. My particular responsibility was waste disposal. Hence, I had an invested interest in the workings of the Commission, and in its eventual findings and recommendations. I attended the presentations to the Commission on the disposal of uranium-laden waste rock and tailings.

One of a small number of principal presenters to the Commission was Elio D'Appolonia who had considerable experience in mine development in the United States and other countries. D'Appolonia was a consultant to regulatory bodies in the US, and he sat on mine design and development review boards. His presentation to the Commission was on the long term storage of uranium mine tailings.

The findings and recommendations of the Commission were disheartening. On February 27, 1980, the Government of British Columbia ordered a seven-year moratorium on uranium exploration and mining. As recently as March 12, 2009, the BC Government issued a Cabinet order that stopped any review of proposed uranium and thorium exploration and development in the province, thereby extending the 1980 moratorium to the present day.

Donald Shields, Retired

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[1] Statement of Evidence of E. D'Appolonia, D'Appolonia Consulting Engineers, Pittsburgh, Pennsylvania. Proceedings of the British Columbia Royal Commission of Inquiry into Uranium Mining, Phase V: Waste Disposal, ISBN 0-7718-8198-3, Page 9.

General role of instrumentation, and summaries of instruments that can be considered for helping to provide answers to possible geotechnical questions. Part 1.

John Dunnicliff

Introduction

This is the first of a series of articles that attempt to identify:

- The general role of instrumentation for various project types.
- The possible geotechnical questions that may arise during design or construction, and that lead to the use of instrumentation
- Some instruments that can be considered for helping to provide answers to those questions.

Of course it is recognized that there may be additional geotechnical questions and also additional instruments that are not described in this article.

The sequence of geotechnical questions is intended to match the time sequence in which the question may be addressed during the design, construction, and performance process, and does not indicate any rating of importance.

The suggestions for types of instruments are not intended to be dogmatic, because the selection always depends on issues specific to each project, and is influenced by the personal experience of the person making the selection. In the tables some of the most likely instruments that can be considered are listed, with other possible types in parentheses. The tables include the term "remote methods" for monitoring displacement. An overview of these remote methods is given in a December 2012 GIN article by Paolo Mazzanti (www.geotechnicalnews.com/instrumentation_news.php). Readers who want to learn more about these methods may want to consider participating in the annual International Course on Geotechnical and Structural Monitoring held in Italy (www.geotechnicalmonitoring.com), where they are discussed in detail.

Part 1 of this series focusses on internally and externally braced excavations. Later parts will include:

- Embankments on soft ground
- Embankment dams
- Cut slopes and landslides in soil
- Cut slopes and landslides in rock
- Tunnels
- Driven piles
- Bored piles (drilled shafts)

Internally braced excavations

General role of instrumentation

The design of internally braced (strutted) excavations is based for the most part on empirical procedures and past experience. The consequences of poor performance can be severe and may on occasion be catastrophic. A monitoring programme may not be required if the design is very conservative, if there is previous experience with design and construction of similar facilities under similar conditions, or if the consequences of poor performance will not be severe. However, under other circumstances a monitoring programme will normally be required to demonstrate that the excavation is stable and that nearby structures are not affected adversely. Depending on the specific needs of each case, the monitoring programme may apply to the wall and struts, to the ground beneath or surrounding the excavation and/or to adjacent structures or utilities.

Summary of instruments that can be considered for helping to provide answers to possible geotechnical questions

Table 1 lists the possible geotechnical questions that may lead to the use of instrumentation for internally braced excavations, together with possible instruments that can be considered for helping to provide answers to those questions.

Externally braced excavations

General role of instrumentation

The general role of instrumentation for externally braced excavations (using ground anchors or tiebacks) is the same as for internally braced excavations. However, it is possible to make regular visual inspections of internal bracing, but external bracing cannot be seen. Although confidence in the performance of an externally braced excavation is increased by conducting a proof test on every anchor, if an anchor subsequently fails, the failure may be progressive and catastrophic. In general, therefore, instrumentation plays a role in three phases of external bracing that are not applicable to internal bracing:

- Testing of *test anchors* during the design phase or at the start of construction, as input to design of the project anchors.
- *Performance* and *proof testing* of anchors during construction.
- Subsequent *monitoring* of selected representative anchors. This` phase may be omitted if a conservative design has been used.

Table 1. Some instruments that can be considered for monitoring internally braced excavations		
Possible geotechnical questions	**Measurement**	**Some instruments that can be considered**
What are the initial site conditions?	Groundwater pressure Vertical displacement Widths of cracks in structures	Open standpipe piezometers Vibrating wire piezometers installed by the fully-grouted method (Pneumatic piezometers) Conventional surveying methods Remote methods Crack gauges
Are the struts being installed correctly?	Load in struts	Calibrated hydraulic jack
Is the excavation stable, and are nearby structures being affected adversely by ground movements?	Settlement of ground surface, structures and top of supporting wall Horizontal displacement of ground surface, structures, and exposed part of supporting wall Change in width of cracks in structures and utilities Subsurface horizontal desplacement of ground Subsurface settlement of ground and utilities Load in struts Groundwater pressure Bottom heave	Conventional surveying methods Remote methods Conventional surveying methods Remote methods (Convergence gauges) Crack gauges Inclinometers In-place inclinometers (Fixed borehole extensometers) (Fibre-optic instruments) Probe extensometers (Fixed borehole extensometers) Surface-mounted strain gauges Open standpipe piezometers Vibrating wire piezometers installed by the fully-grouted method (Pneumatic piezometers) Probe extensometers
Is an individual strut being overloaded?	Load in strut	Surface-mounted strain gauges
Is the groundwater table being lowered?	Groundwater pressure	Open standpipe piezometers Vibrating wire piezometers installed by the fully-grouted method (Pneumatic piezometers)
Is excessive bottom heave occurring?	Bottom heave Subsurface horizontal displacement	Probe extensometers Inclinometers In-place inclinometers

Summary of instruments that can be considered for helping to provide answers to possible geotechnical questions

Table 2 lists the possible geotechnical questions that may lead to the use of instrumentation for externally braced excavations, together with possible instruments that can be considered for helping to provide answers to those questions.

Table 2. Some instruments that can be considered for monitoring externally braced excavations

Possible geotechnical questions	Measurement	Some instruments that can be considered
What are the initial site conditions?	As in Table 1	As in Table 1
What is a suitable design for tieback anchors (by constructing and testing *test anchors*)?	Load in tieback Displacement at head Load transfer in grouted zone	Load cells Dial indicators Surface-mounted strain gauges
Are the tiebacks being installed correctly (by *performance* and *proof testing*)?	Load in tieback Displacement at head	Calibrated hydraulic jacks (Load cell) Dial indicators
Is the excavation stable, and are nearby structures being affected adversely by ground movement?	As in Table 1, except for load in struts Load in tieback	As in Table 1, except for load in struts Load cells (Calibrated hydraulic jacks and load cells: *lift-off tests*) Surface-mounted strain gauges
Is the groundwater table being lowered?	As in Table 1	As in Table 1
Is excessive bottom heave occurring?	As in Table 1	As in Table 1

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Paolo Gazzarrini

Overture

41st episode of the Grout Line and for this issue an article (the first part of two) related, again, to the GIN (Grouting Intensity Number) method for rock grouting.

I received, few weeks ago, a long article written by Clif Kettle, Technical Manager of Bachy Soletanche Ltd., Burscough, Lancashire, UK,(*clif.kettle@bacsol.co.uk*) and Maren Katterbach, Project Engineer, Lombardi Engineering Ltd., Minusio, Switzerland (*maren.katterbach@lombardi.ch*). The article was related to the contractor point of view of the use of this grouting philosophy and it was divided in two parts; part one, refreshing about the basis of the GIN grouting method and procedures, mainly in the practical application, the second related to several grouting case histories. Considering the length of the article, I am publishing it in two parts, as the article was received.

A preliminary comment of mine for my 25 readers. This grouting method/theory/procedure/philosophy has been object of several controversies (also in this Grout Line a few years ago), discussions and, maybe, wrong interpretations/applications in the past and Dr. Lombardi tried to re-explain and clarify his concepts also from these pages.

With time, nearly 30 years, the GIN method has evolved in the field and these two articles are giving us a European Contractor/Engineer perspective that, in my opinion, helps enormously to clarify the essence and the advantages of this grouting method.

At the end of this first part of the article I have added some comments of mine related, again, to the differences between North American and European approaches.

Enjoy your reading and stay tuned for the March 2016 issue with the second part with a few case histories!

- A couple of housekeeping items: The first is related to the G-I (ASCE/Geo-Institute) Grouting Committee that is organizing the 5th International Grouting Conference for July 2017 in Honolulu, Hawaii. For this, please, get ready to prepare papers and to attend. Further information will follow. Again, stay tuned!
- The second is about, again, the GI-Grouting Committee and its web page. A new webpage, was launched a few weeks ago by the G-I, and inside you can find the web page of our Committee. Updated scheduling, news, minutes of meetings etc, are available there. Every grouter is encouraged to visit and, why not, comment. And new active members are already welcome!
- The third item is related to the Grout Line web page (www.groutline.com). Since a few weeks ago, login is required in order to access the articles. It is a very simple operation, but necessary so I can keep track of my 25 readers.

Practical application of the GIN concept (Part 1)

Clif Kettle & Maren Katterbach

Designer's overview

The GIN concept is a self-regulating approach of controlling simultaneously both the injection pressure and rate of injection, to avoid a combination of high volumes and high-pressure, whilst at the same time setting defined limits on maximum volume and maximum pressure. In general terms the GIN concept aims to optimize the grouting process. In particular, it aims 1) to grout only where absolutely necessary, in this way avoiding any waste of grout and 2) to use highest practicable grouting pressures without causing any damage, in order to enhance the efficiency and success of the grouting operation.

This concept was first introduced more than 30 years ago by Eng. Lombardi and Eng. Don Deere, with the intention of avoiding damage to the fissured rock formation, whilst greatly improving the efficiency and effectiveness of grouting operations. One of the intentions of the process is to equalise the radius of flow in fissures of varying widths.

Remarkably, with all the advancements in grouting over the last decades, the GIN concept has remained largely intact and has proved to be a reliable tool to manage efficiently the grouting process under varied conditions in numerous projects worldwide. With its well-founded physical basis, its generality, and finally its simplicity, the GIN concept clearly and consistently illustrates that grouting does not, and should not, represent an obscure art.

Contractor's overview

Bachy-Soletanche personnel have been using the GIN concept for rock grouting for more than 30 years in a wide range of rock conditions, from karstic limestone, through finely fissured chalk, to heavily fractured sedimentary and volcanic formations, and have come to value the technique for its simplicity and efficiency, to the extent that it is now a prime consideration when reviewing any rock grouting solution for either block consolidation/impermeabilisation, or as a grouted cut-off.

The GIN technique is considered not so much as a method of grouting, but simply as a tool, one of many essential tools used by the grouting engineer to achieve a successful outcome. As with any tool used in any type of work, it requires understanding, skill, and experience to be able to employ it effectively in the workplace. Furthermore, GIN grouting involves experienced observation and interpretation throughout the grouting programme. Based upon the initial observed results, the GIN value, and the various injection parameters, should be adjusted where necessary during the course of the grouting programme, but thereafter, the objective should be to change as little as possible to maintain a consistent strategy.

The technique has proven itself on worksites where other techniques have failed, and has delivered a high quality of ground treatment in challenging rock conditions, whilst at the same time providing significant economic benefit for both client and contractor alike.

For success and maximum efficiency it is essential that the technique, as with all techniques, is configured to suit the local ground conditions. This may seem obvious, but there have been many cases of specifications and grouting strategies being too rigidly applied, sometimes simply copied from elsewhere, in the expectation that these can be imposed on the ground, and that the ground will comply. Clearly, it will not, and thus this approach is predestined for failure.

Within the Bachy Soletanche group, the GIN concept of fissure grouting in rock is seen as a major advance in the practical application of rock grouting technology. This view is also widely held amongst practising contractors due to the simplification of the core injection process, the self-regulating control of excessive hydro-fracture pressures, and the improved facility for comparison and interpretation of the grout injection data across numerous phases of injection.

On the following pages, some general technical aspects related to GIN grouting will be discussed. In the next Groutline issue (Match 2016), several case histories of projects in which Bachy-Soletanche has been involved are presented.

Technical aspects related to GIN

Basic rules for GIN injection

When it was introduced some 30 years ago, the grouting intensity number was just a numerical value, defined as the product of injected grout volume and applied pressure, GIN = P.V. However, over time, with technological advances and improved field experience of the approach, further aspects related to grouting of fissured rock masses have been developed and incorporated within GIN injection.

Despite various developments, the basic GIN concept itself has remained unchanged across the industry, so that today there is a broad consensus as to what constitutes the essential features of this technique, which can be summarized as follows:

- application of a **single GIN value**, the product Pressure x Volume, which is constant for all stages and boreholes, or (at least) all stages within a given phase of injection, and preferably for the entire grout programme. The GIN boundary curve defines the limits within which injection should be executed.
- application of **a rheologically stable grout mix** whose design and constituents is appropriate for the rock conditions and desired residual permeability.
- use of a **single**, rheologically stable, **grout of low water-cement ratio**. Without this, it is impossible to compare grout absorptions between different phases and injection on a similar basis.
- establishment of a **maximum injection pressure**.
- application of a **minimum effective flow rate**, the equivalent of a refusal criteria, to terminate injections if injection flow rates become too low to be practicable.
- establishment of **consistent injection parameters** for maximum pressure, maximum volume, and uniform injection rate up to the point at which the GIN curve intersects the GIN envelope boundary curve.
- once the injection has reached the boundary curve, a **progressive reduction in the maximum pressure**, following the GIN boundary curve as the volume increases, continuing up to the point at which either maximum target volume, or minimum flow rate, are recorded.
- estimation of the **target volume**, based upon knowledge of the rock formation and the required ground treatment geometry
- plotting of results in the format of an **Equivalent Lugeon**, provides an indirect measurement which allows an approximation of the rock mass transmissivity with water. This can provide a very useful means of observing in real time the progressive reduction in permeability achieved by successive phases of grouting, and even during an individual injection.
- execution of **test grouting** as **direct unambiguous way** to confirm the appropriateness of the mix design and grouting parameters.

With the appropriate planning, equipment, and control systems, GIN grouting is very simple to apply in practice.

The function 'Equivalent Lugeon' has been recognised by many practitioners. This function, calculated on the basis of the ratio between the viscosity of the grout and the viscosity of water, is useful for tracking the evolution of the injection, and the progressive reduction in permeability and transmissivity. It is noted that Equivalent Lugeon is actually a rather inappropriate and controversial name for this parameter, and its use gives rise to misunderstanding and resistance amongst the grouting fraternity. However, since this phrase is already widely used, it is difficult to change its name without generating confusion.

Establishing the GIN value

In general terms the GIN concept helps to obtain the best grouting result with minimum effort. The three underlying parameters to achieve this are the grouting intensity number itself, the maximum pressure and the maximum (target) volume. The GIN value is the product of P, the injection pressure, and V the cumulative volume. It is a constant for any given injection, so that the pressure decreases as the injection progresses. The plot of this function forms a limiting boundary curve, (See Figure 11), which helps to avoid a combination of high pressure and high volume, which could have the potential of damaging the rock formation and risking surface heave. The curve, plotted with P on the y axis, and V on the x axis would at infinity by asymptotic. The extent of the curve is therefore limited by a cut-off at P_{max} (maximum allowable pressure), and a cut-off at V_{max} (target injection volume for the injection stage).

The definition, purpose, and the selection of appropriate values for the GIN, P_{max} and V_{max} are discussed below.

GIN value

The choice of the proper grouting intensity number (GIN) itself is based on both, geological conditions as well as on the project design and requirements.

Before addressing the determinant geological factors, it needs to be noted that the GIN concept has been specifically developed for, and is therefore intended only for, fissure grouting. Like for any other grouting method, special attention must be paid to larger voids, which should be filled with a low mobility grout (LMG) or another appropriate low cost material. This confutes the sometimes still existing misconception that GIN grouting is generally not applicable in limestone. In fact, numerous foundations composed of fissured limestone have been already successfully grouted using the GIN technique. If local conditions, such as the presence of large dissolution features often associated with this type of rock, called for it, a corresponding special treatment to fill these voids was simply adopted.

As with the choice of the proper grouting method, be it fissure grouting or void filling, the selection of the adequate GIN value depends on the local site conditions and the expected final result. Whether the purpose of grouting is to reduce the permeability of the rock mass or to strengthen the foundation, the GIN value on a site can be generally correlated to certain geotechnical zones. Where a site is characterized by highly variable rock mass conditions distinguishing several geotechnical zones, this might indicate a need to apply different GIN values. Generally, for rock masses of good quality, a higher GIN value can be used, whilst in weaker zones of lower strength, grouting should be performed more cautiously, by applying a lower grouting intensity. Table 1, as a rough indication, shows the relationship between some common GIN values, the grouting intensity scale, and in accordance with the above, gives a direct correlation with the geomechanical rock mass quality.

Thus, *Grouting intensity number, GIN ~ Rock mass quality*

further as the grouting works progress. However, any abrupt and frequent changes are to be avoided in order to keep the control and analysis of the grouting as simple as possible. Occasional modifications might be necessary, but should be always based on a rational basis to avoid the grouting becoming confusing and obscure. It is noted that test grouting sections on the site into the actual rock mass allow to significantly reduce any possible changes of the grouting design to a minimum.

Table 1 GIN values with typically correlated geomechanical rock mass quality ranges. Note: the indicated GIN values should be consistent with the project requirements, and borehole location.

Intensity	GIN [bar. litre/m]	RMR		RQD	
Very high	> 2’500	81-100	very good	91-100	excellent
High	1’500 - 2’500	71-80	good	76-90	good
Moderate	1’000 - 1’500	41-70	fair - good	51-75	fair
Very low - low	< 500 - 1’000	<40	very poor - poor	<50	very poor - poor

It is worthwhile noting that, in contrast to many other fields of engineering, the design of a grouting job strongly depends on the rock mass - a natural medium which is not designed by ourselves. As consequence, there is always an unavoidable uncertainty in the definition of the generic mechanical or hydraulic parameters, and the engineer must be aware of this variability when using those parameters as basis for the grouting design.

It frequently occurs that the actual rock mass conditions do not correspond to the ones anticipated and assumed in the initial design phase. If this discrepancy becomes significant, it might indicate the need to change the grouting intensity according to the new findings. Optimally, the GIN value for any given rock formation should be chosen at the beginning of the design procedure, and kept constant for each phase, or for the whole, grouting programme. For some sites the GIN value might require to be adjusted after the initial results are analysed, and possibly even reviewed

Apart from geological aspects, the general project requirements and grouting objectives should be carefully considered when establishing the GIN value. For many applications, it is possible to assign priorities to certain zones, which are then treated using higher grouting intensities.

Thus, *Grouting intensity number, GIN ~ Project requirements*

Considering a grout curtain, for example, after impounding of the reservoir, a lower water pressure is to be expected in the higher abutments than in the central part of the dam. Consequently, a lower grouting intensity might be acceptable at higher locations. A similar allocation can be made for the constraints related to the hydraulic gradient imposed by the project. The hydraulic gradient in the rock zone to be treated will highest at a shallow depth and diminishes quite fast while depth reaching its minimum in the lowest point of the curtain. Accounting for the fact that in this lowest part the real efficiency of the curtain is by definition zero, the requirements for the grouting intensity might actually also be defined less stringent in this lower zone.

In this way unnecessary grouting in zones of minor importance can be avoided, while the main effort can be focused on the most relevant zones. This helps to significantly optimize the whole grouting process.

<u>Accordingly, the GIN number itself incorporates both geological and project design aspects. The intensity is therefore directly related to the rock mass quality as well as the relevance of the grouting result for the project.</u>

Once selected, the GIN value controls the injection parameters within a safe working envelope. However, the GIN value needs to also reflect the constraints of the practicable values for the minimum flow rate and minimum controllable pressure of the grout pump (typically 200-300 l/ hr, and approximately 2 bars).

For any given grout type, and injection rate, the evolution of the GIN value over the duration of the injection will depend upon the rock conditions, the grout rheology, and the injection rate. Once the plot of P x V reaches the boundary curve, the injection flow rate, controlled by computer piloted grout pumps, is progressively reduced or increased automatically to maintain the product P x V at or just below the GIN curve until either the maximum target volume is injected, or until the flow rate reduces to a minimum practicable level, at which point the injection is complete.

When establishing a GIN value it is therefore also necessary to consider particularly the likely flow rate during the latter stages of the injection, (approaching the target volume) to ensure that this is compatible with the minimum practicable flow rate for the grout pump, and grout gelling properties, to avoid line blockage.

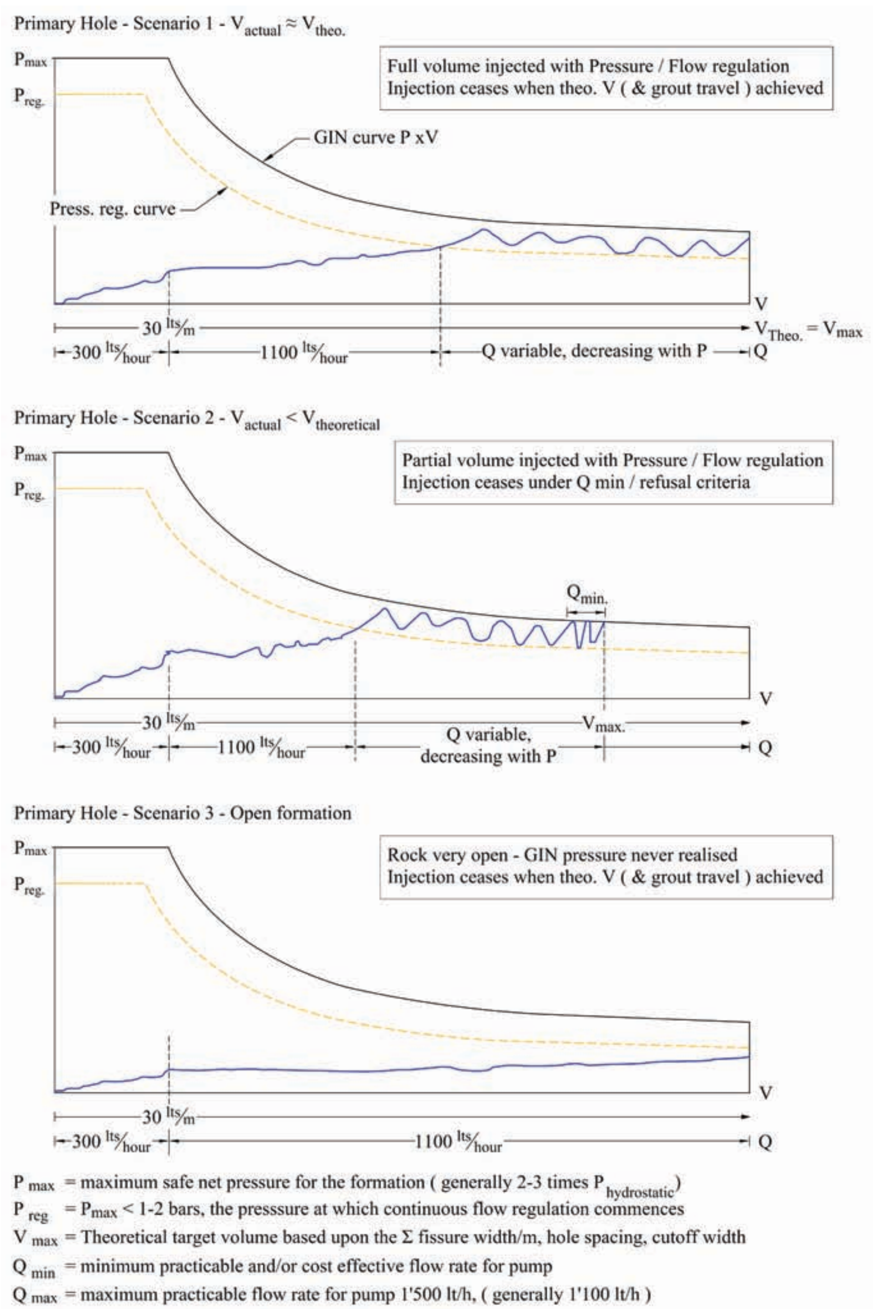


Figure 1. Typical examples of the evolution of the GIN value.

Application of a single GIN value allows direct comparison of the graphical and numeric data for individual borehole stages, and for the various phases of injection. It also allows the grouting engineer to rapidly assess and gain a feel for the progress of a single injection and / or the progress of the grouting programme, either by observation of the real-time plot of the GIN curve and the evolving GIN value during the injection, or by visual inspection of the graphical plots on completion of the daily injection programme. Figure 1 gives typical examples of the evolution of the GIN value, within the GIN boundary curve.

Maximum injection pressure

The maximum pressure limit P_{max} serves mainly to select the proper grouting equipment, such as pump, tubes and valves. Like the GIN itself, it should be defined so that it complies both with the rock mass properties and project requirements.

If the purpose of grouting is, for example, the impermeabilization of a dam foundation, the maximum pressure should be chosen according to the expected future water losses and uplift pressures after impounding. It has to be sufficiently high in order to avoid a fissure opening when the reservoir is impounded. A common value for the maximum pressure at the borehole mouth is around 2 - 3 times the future water pressure at that location. Another important aspect to be considered when selecting the proper maximum pressure is the allowable hydraulic gradient of the rock mass. In this: the higher is the hydraulic gradient the higher shall be the maximum injection pressure.

In practice, the maximum pressure can be set in a number of ways. The most reliable method remains certainly the execution of grout test sections on site in the same conditions using the proposed mix design. Another indirect method is to conduct hydro-fracturing tests in the pre-injection investigation boreholes, and to apply a factor of safety to the measured hydro-fracture pressure. In contrast to grouting test sections, for hydro-fracturing tests there is no volume constraint for the water, which is first of all risky. Secondly, acknowledging the difference in water and grout mix, a careful evaluation of the test results by an experienced person is required to be able to extract the desired information for the actual admissible grouting pressures. Alternatively, an estimation may be made with the confining overburden and surcharge pressure, or the limit may even be set on an empirical basis based upon previous experience in similar rock conditions and/or depths of injection.

It is important to recall that the GIN technique is actually self-regulating. Any possible adoption of the pressure with depth to avoid grout outflow or

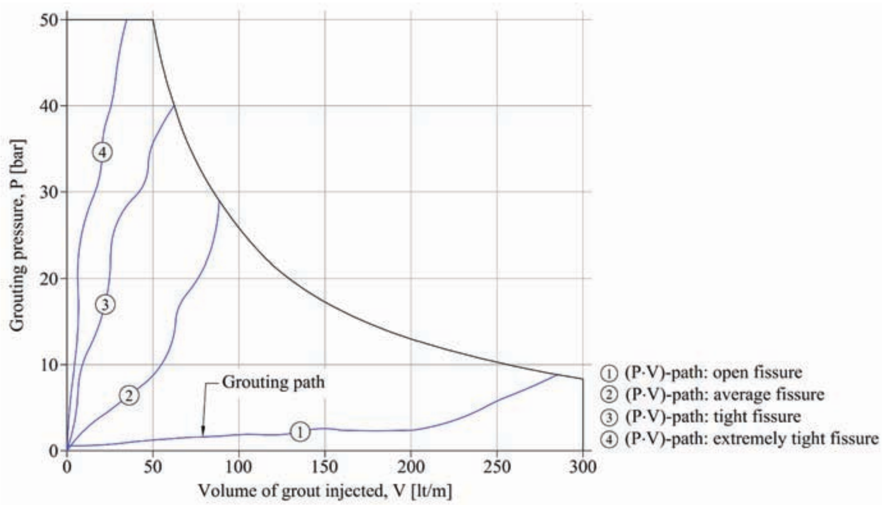


Figure 2. Grouting paths for different fissure openings, illustrating the self-adaptive nature of GIN grouting.

damage due to too higher pressures, as is sometimes erroneously done, becomes therefore superfluous. Following the GIN concept, the grout takes near the surface or gallery, where the fissures generally tend to be rather open, automatically increase, while the pressure remains rather low. At depth, on the other hand, the openings are generally smaller so that less grout is absorbed. As shown in Figure 2, the grout path in this latter cases (grout paths 3 & 4) is steep reaching quickly higher pressures. Therefore, respecting this self-adaptive nature of GIN grouting, once a certain maximum pressure is defined, it should be kept constant. Changing systematically the maximum pressure in function of depth does not only unnecessarily complicate the whole grouting procedure, but it also carries the risk of stopping grouting before the natural equilibrium is actually reached, resulting in an incomplete execution of the works. The only zone where a certain pressure limitation might be acceptable is the upper 5 m, in order to avoid grout break-out to the surface, especially if grouting is not performed through a concrete slab or similar. To ensure an efficient grout result along the entire borehole length, it is common practice to increase in addition

In this respect, it is recalled that the adequacy of the selected maximum grouting pressure can be best confirmed by several representative grouting test sections.

Maximum grout take (target volume)

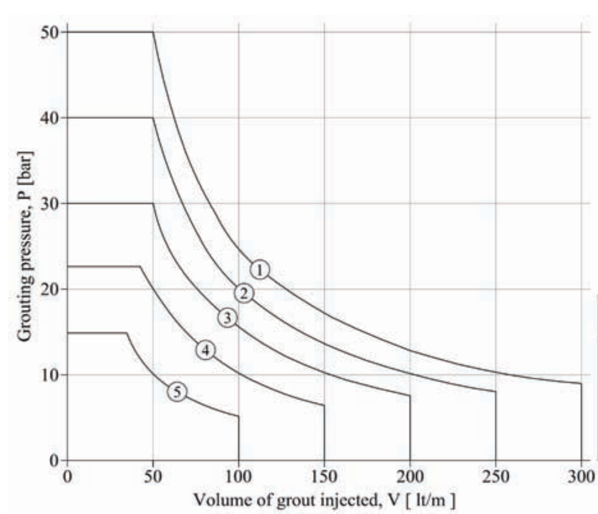
The maximum grout take does actually not present an absolute stop criterion. It rather defines a decision point on whether to

- Continue grouting
- Terminate grouting
- Pause grouting and restart later after setting of grout
- Abandon the hole & drill another one nearby
- Modify the grout mix

In contrast to the grouting intensity number and the maximum pressure, this parameter is mainly defined considering economical rather than physical aspects. A rough indication of commonly chosen maximum grout takes, V_{max}, for certain grouting intensities is given in Figure 3.

Mix design

One of the key aspects of the GIN concept is the use of a single stable grout mix. The mix should be formulated to achieve the specified performance criteria as efficiently as possible (i.e. the minimum number of boreholes, the minimum number of injection phases, and the optimum injection rate throughout each individual injection). Its selection and design is based upon a thorough understanding of the site rock conditions, including fissure widths. It stands to reason that one of the most important aspects actually limiting the groutability is the maximum cement grain size relative to the fissure width. As a general rule, for a fissure to be groutable, its aperture should be at least three times the maximum grain size of the cement. Finally, the mix is also of low water-cement ratio to ensure both long-term strength and durability, and the avoid-



Nr.	Intensity	GIN [bar·lt/m]	P_{max} [bar]	V_{max} [lt/m]
1	very high	> 2'500	50	300
2	high	2'000	40	250
3	moderate	1'500	30	200
4	low	1'000	22.5	150
5	very low	< 500	15	100

Figure 3. Typical range of GIN values, as well as corresponding maximum pressures and volumes.

ance of bleed within the voids and fissures of the formation.

Stable mix

Generally a stable mix is a grout consisting of a cement-based slurry, with additives if necessary, to ensure that no water is expelled from the suspension when injected at pressure (i.e. no pressure-filtration). The stability of the grout ensures that

- the grout rheological properties remain constant throughout the injection to maintain the fluidity and penetration capability
- the progressively reducing absorption of grout can be clearly observed, understood, and measured, as the works progress
- no water filled zones are left

Consistent rheological properties ensure a realistic comparison of grout injection data between subsequent phases of injection, and during the course of a single injection.

This is why the mix should not be fluidified with excess water. Water should be mainly considered as transport medium for cement grains not as physical component of the mix.

Current practice is to employ a grout of low water cement ratio (typically 0.6 -1.1), so that once an individual injection is completed, the potential for bleed in-situ is minimised. It also ensures long-term strength and durability reducing the requirement for successive re-injections.

Single mix

For successful and efficient grouting, it is highly recommended to inject a single grout type with a consistent water/cement ratio for all injections and all phases of the works. Combined with the stability of the grout, a single mix enables the accurate verification and control of the increasing competence and water-tightness of the strata with the grouting works progress.

Recognizing the importance of using a single mix is one of the main aspects where the GIN approach differs from classical grouting practice of 30 years ago. Traditionally, the w/c ratio was lowered in steps (see Figure 4) to increase the cohesion, and in this way lower the normalized pressure, P/c. The introduction of the GIN concept can be said to present a turning point away from this traditional approach of thickening the mixes in steps.

For GIN, (as indicated by the blue line in Figure 4), it is recommended to

- Use 1 unique stable mix throughout the grouting works
- Limit the grouting pressure with increasing volume take

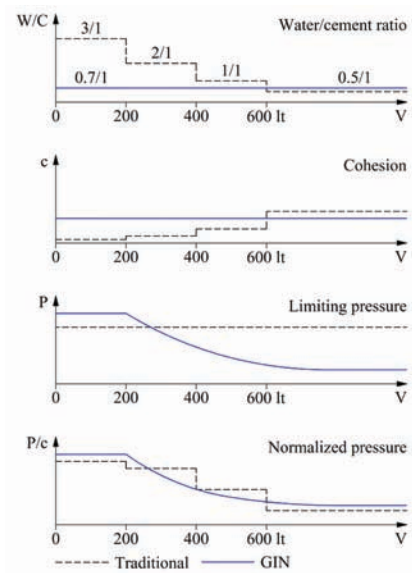


Figure 4. Mix and pressure evolution -Traditional versus GIN grouting.

- Reduce the normalized pressure (P/c) by progressively decreasing the pressure.

The use of a single, stable, grout mix avoids many potential errors in mix formulation and in the interpretation of the most relevant injection data - the volume per linear meter injected. In the past, much effort has been expended in trying to accurately convert injected volumes into a dry weight of material per linear metre - a pointless exercise in terms of the specified objectives and technical management of the works, and only of interest for assessing payment.

Multiple mixes, changed during a single injection according to certain volumetric or pressure criteria, have resulted in a flawed understanding of the grout absorption due to the fact that insufficient consideration was taken of the distance over which the grout has been pumped, and/or the volume of grout in the system. There have been sites where mixes have been changed in a rigid succession, when one of the mixes in the sequence has been still wholly or partly within the delivery system, without ever reaching the point of injection. Consequently, the basis for changing the grout mix was flawed, and a calculation of the total dry weight of material injected into a grout stage at the time of refusal was incorrect, so that decisions on subsequent injections were based on a false premise and understanding.

The changing of mixes, in particular the thinning or thickening of the grout mix already in the system, is prone to errors of mix formulation and preparation, whether manually or automatically batched, and this has led to errors in calculating the effects of varying viscosity and head loss, the extent of pressure filtration and sedimentation, and hence in understanding the effective penetration of grout into the formation.

However, the real advantage of a single mix is that it is designed specifically for the rock conditions on site, and particularly for the finer fissures required to be injected to achieve the specified residual permeability,

Another real and valuable advantage is to enable a simple and direct comparison of injections from stage to stage, hole to hole, and between successive phases of grouting. This is invaluable in understanding and visualising in real-time the improving condition of the rock mass and reduction in mass permeability.

Further, providing care is taken with the mix design to control the evolution of the mix viscosity, the gel time, and the setting time, so that the mix remains rheologically consistent throughout the injection, the injection can be used as a surrogate hydraulic or packer test. Real-time plotting of the Equivalent Lugeon can indicate visually the increasing 'tightness' and reducing permeability of the formation as the injection proceeds. Field experience has shown this value - the misnamed Equivalent Lugeon - to be a remarkably good and consistent indicator of the true residual permeability, expressed in Equivalent Lugeons.

In summary, a carefully designed single mix greatly facilitates the work of the grouting engineer and the operatives in the field, has real technical advantages, and provides an accurate and reliable basis for comparison of grout absorptions between different injections stages and different boreholes, and between successive phases of grouting.

Use of multiple mixes, including accelerator and/ or gelling agent

When employing the GIN grouting, the flow rate is automatically controlled to ensure that the function P x V remains within the boundary curve. It follows that towards the end of a given injection, the injection rate may be approaching the limit of the pump, i.e. approximately 180 L per hour.

Considering for example a grout curtain. Due to its geometry and the need to keep a constant length for the grout injection line to ensure constant head loss at a given flow rate, the total volume of grout in the injection system might be as high as 450 L (150 L in the grout line, 250 L in the grout agitation tank, and 50 L in the grout Packer and stage). Clearly, if the new mix is introduced into the system, whether with or without an accelerator, it could take up to 2 hours for this mix to arrive at the point of injection, particularly as flow rates are progressively reduced.

This suggests that the use of an accelerated mix, where the accelerator is added at the mixing station, is not compatible with the GIN idea when following the standard GIN procedure, as this could lead to premature sealing of the borehole before the required volume is injected. Therefore, accelerated mixes might only be applicable when either:

- a pre-injection stage water test indicates an exceptionally high Lugeon value
- there is a high hydraulic gradient across the injection zone, with risk of grout dissipation
- grout is being freely absorbed with minimal pressure increase at the point where the target volume has been injected

at which point a decision could be made to introduce an accelerated mix for a single one-off, non-GIN injection to deal with a significant local feature such as a major fissure or preferred seepage path. Whether an accelerator is added for a single on-off injection, or used systematically in poor or voided ground, the accelerator should be added at the point of injection, via the packer, using a separate supply line for the additive, an in-line mixer, and with a variable flow or proportioning pump to adjust the flow according to the rate of injection to maintain the correct additive proportion in the mix.

The same considerations should be made to changing the grout mix at any point within a GIN injection, since as the injection progresses, and the flow rate gradually reduces, it is highly likely that the new grout mix could still be advancing within the injection lines at the time that the injection is nearing completion. We would strongly recommend therefore the use of a single grout mix throughout any GIN injection, and wherever possible, the use of a single grout mix throughout the whole injection program for a given phase of the works.

Grouting procedure

Tracking the GIN boundary curve

Injection of an individual stage proceeds on the basis of pre-set injection rates, until the value of P x V reaches the limit of the boundary envelope defined by the GIN value. Once the product of P x V reaches the boundary envelope, it is necessary to progressively reduce the flow rate as the cumulative volume increases, in such a manner that the product of P x V remains constant at or just below the limiting GIN value. This operation could be, and has been in the past, carried out manually - but this might be extremely difficult. Current best practice is to employ piloted grout pumps which have the facility to be controlled by computer at all stages of an injection, utilising continuous real-time feedback of data on the pressure, cumulative volume, and flow rate to the grouting computer, in such a manner that in real time the computer can respond to the incoming data and can automatically slow down the rate of pumping to allow P x V to track the GIN curve until one of several criteria are reached.

These are

- maximum pressure - no further injection is possible without exceeding the allowable pressure
- maximum volume - the cumulative volume of grout injected has reached the target limit for the borehole / injection
- minimum flow rate - this is a condition where in order to maintain the plot of P x V coincident with the boundary curve of the GIN envelope, the injection rate falls to a level which is impractical, un-desirable on economic grounds, or poses considerable risk of blockage of the grout pump and/or injection lines.

Consistent injection rate

There is no inherent advantage, technically or commercially, to either client or contractor in injecting grout slowly.

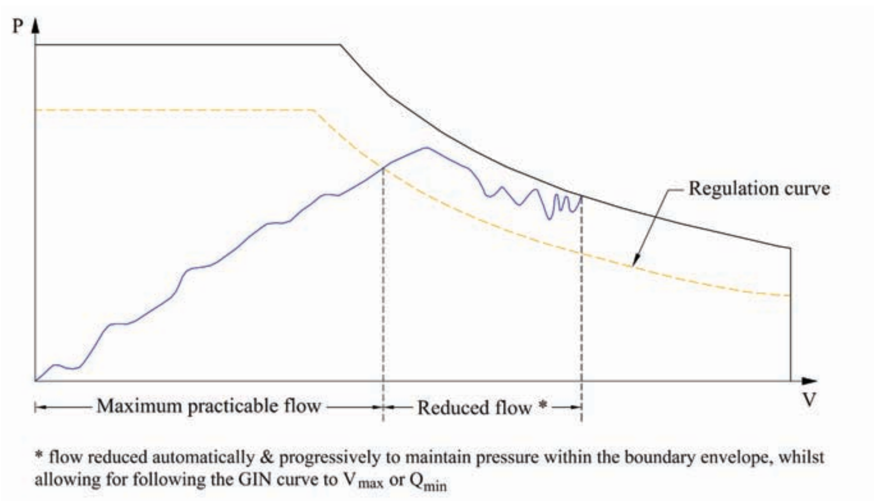


Figure 5. Flow Regulation during the grouting process.

Provided that the limiting grout pressures are not exceeded, the aim should be to pump as quickly as practicable. The GIN technique ensures that the limiting pressure is progressively reduced as the total injected volume increases, and this limit is defined and enforced by the GIN boundary curve.

It is prudent to limit the injection rate over the first 15-50 L to avoid immediately reaching the maximum limit pressure, and modern control measures allow for an injection rate of, for example, 300 L per hour until this volume has been placed. Thereafter, the pump can be programmed to seamlessly and automatically increase injection rate up to its practical maximum, typically in the range 1'000-1'200 L per hour. This injection rate should ideally be constant for all injections, and each injection will continue at this rate until the plot of the GIN value P x V approaches to within approximately 1 bar below the GIN boundary curve.

Practical experience has shown that it is convenient to define a certain regulation zone, when approaching the GIN curve, for which a reduced flow rate is imposed. As shown in Figure 5, this zone is bounded by the GIN curve itself and by a parallel regulation curve typically at around 1-2 bars below the GIN value. Within the regulation zone the pump flow rate varies automatically according to the cumulative grout volume and the rock conditions, to maintain the GIN plot within the regulation zone until the injection terminates on minimum flow or maximum volume. The path of the GIN plot and the point at which the GIN plot intersects the boundary curve will be dependent upon the mix, the pump injection rate, and the rock characteristics. Once the cumulative volume injected reaches the target volume for the stage, or the pump reaches its minimum practicable and/or economic pumping rate, the injection terminates automatically. The target volume and the minimum flow rate are all pre-set into the software and cannot be accidentally exceeded.

Once automatic regulation commences, limiting the injection rate, for low grout quantities, for too long a time in this regulation zone, would make the grouting works unnecessarily complicated and uneconomic. There are mainly two options for the termination criteria – either continue grouting at a reducing flow rate until the flow rate reduces to a pre-determined rate (somewhat equivalent to a classical 'refusal' criteria), or the GIN curve is followed until the previously defined maximum volume is reached.

Applying the same criteria to every single injection ensures that the graphical plot for each injection can be compared with that of every other injection, and can provide a great deal of information about progress and success of the individual injection and the progress of the works. It also, together with the constant GIN value and mix characteristics, adds greatly to the substance and accuracy of any numerical analyses.

A key element of this visual inspection is to see on completion of the injection whether the full target volume has been injected, or whether the injection is terminated too early. The grouting engineer can see at a glance what percentage of the target volume has not been placed, and, can make a judgement as to whether this is due to improving rock conditions and reduced transmissivity, or whether the grout mix is inappropriate for the formation, and it allows him to see whether the GIN value is appropriate or not. If he has any concerns on these issues then, of course, he must be prepared to modify the parameter accordingly. However, this should ideally be done for all remaining boreholes. Varying the injection parameters for each individual stage renders realistic and systematic analyses of the results extremely difficult, and prevents the application of some very valuable comparative analyses.

To avoid such an unnecessary complication of the grouting process, it is advisable, in the early stages of the project, to immediately drop back and carry out one or two secondary injections after the first 3-4 primary holes have been completed, to verify that the assumptions made in terms of target grout volume, GIN value, and the optimum injection parameters, are correct. The parameters should then, if required, be modified at this early stage and maintained unchanged wherever possible for the remainder of the works to keep the grouting works as clear and manageable as possible.

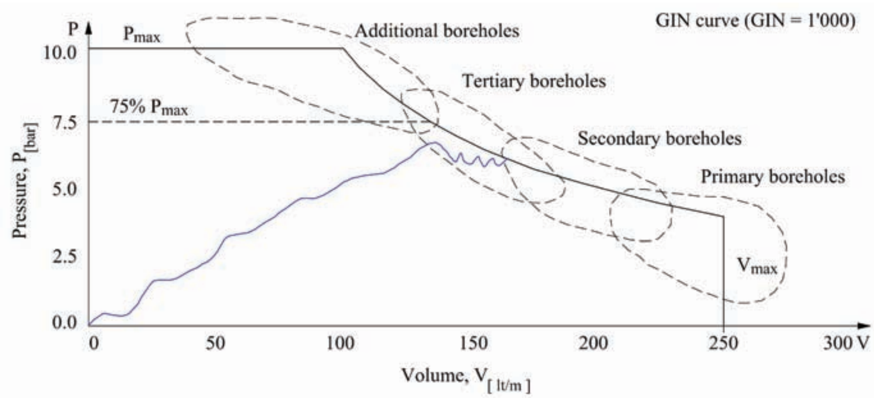


Figure 6. Grouting development from stage to stage and decision criterion for additional boreholes.

Minimum flow rate

The minimum flow rate set for the injection should be a pragmatic decision based upon the characteristics of the pump, technical and cost efficiency considerations, and understanding of the gel and set times of the selected grout, and especially upon examination of the GIN curve and the implied injection pressures at the point on the curve where the maximum target volume has been placed. If, at the maximum target volume, either the minimum flow rate defined by the GIN curve is below the minimum desirable injection rate, or the injection pressure is too low for accurate regulation then the design GIN value may have to be increased accordingly.

These considerations need to take into account the experience of the grouting engineer in similar rock conditions and with the characteristics of the equipment being used. There is no technical or commercial advantage in continuing the injection to a point where any further minimal improvement in the rock condition is not justified by the cost of continuing injection, or beyond the point at which there is a risk of grout line blockage or inefficient injection due to a change in the rheology of the grout mix.

Successful completion of grouting

Decision for additional boreholes

In accordance with the rock mass conditions and project requirements, grouting might be systematically executed from primary or secondary boreholes, depending on the hole spacing. The decision for additional, i.e. tertiary or quaternary boreholes is then based on the final grouting pressure reached. According to the GIN concept, and as a result of the split-spacing borehole pattern, grouting is a self-adaptive procedure: first wide fissures are grouted at rather low pressures, before by the following higher order boreholes increasingly smaller openings are filled using higher pressures, as shown in Figure 6.

Consequently, when applying the GIN technique, it can be observed that in general the final grouting pressure does continuously increase from phase to phase, whilst the grout takes are generally decreasing. This development from the lower right to the upper left of the GIN curve, reflects in fact that for each phase the widest remaining joints, not injected during previous phases, are filled. Such grouting results are therefore considered much more meaningful in terms of the actual groutability than any water pressure tests.

Generally, the grouting works are said to be completed if the GIN curve is reached at 50 to 75% of the final pressure. If the grouting path intersects the GIN curve at lower pressures, for example as shown in Figure 16, this phase cannot yet be considered finished and additional boreholes or phases are to be executed. These

Table 2. Guidelines for acceptable foundation permeabilities, according to Houlsby and ranges for typical allowable hydraulic gradients allocated to different dam types.

Dam Type	Curtain	Recommended Lugeon	Typical allowable hydr. gradient Δ
Concrete Dams	Single row	3 - 5 Lu	5 - 10
	Multiple row	5 - 7 Lu	1 - 5
Embankment dams with narrow core (earth / rockfill)	Single row	3 - 5 Lu	5 - 10
	Multiple row	5 - 10 Lu	1 - 5
Embankment dams with a wide core & membrane faced dams	Single row	5 - 10 Lu	1 - 5
	Multiple row	7 - 15 Lu	1 - 2
All dam types with foundation material prone to piping or wash-out by seepage in general	Single row	3 - 5 Lu	5 - 10
	multiple row	2 - 4 Lu	5
All dam types, if water loss by seepage becomes relevant for the project, and thereby warrants considerable expenditure to stop it	Single and multiple row	1 - 2 Lu	>25

additional boreholes do not necessarily need to be drilled to full depth. Instead, their optimum depth should be selected based on the grouting results of adjacent boreholes at certain depth intervals. This simple design consideration shows how, by proper integration of the observational method within the grouting procedure, the full benefit of the self-adaptive nature of the GIN concept can be gained, thereby achieving a complete, efficient, cost-effective, and safe grouting job.

Acceptable final permeability

Before defining an acceptable final permeability for a grouting job, one should first think about what might actually be the consequence of the seepage and/or leakage caused by it. There should be a clear differentiation between seepage, which is defined as interstitial movement of water in the foundation, or the abutments, and leakage, which is flow of water through holes or cracks.

Taking a closer look, it quickly becomes clear that foundation permeability may directly affect the stability of the structures to varying degrees, mainly depending on the dam type and height. Whilst for rock fill dams, for example, a certain amount of leakage is common and is rather of little relevance, for concrete dams, in particular if they are large, the same leaks might already significantly impair their safety.

This distinction was already recognized by Lugeon in 1933, when he came up with first indications for allowable foundation permeabilities. He suggested a limiting Lugeon value of 3 for small dams and a Lu < 1 for large dams, respectively. Based on subsequent experience and critical expert reviews, this concept has been further refined over time, in particular focusing on the actual warranty for grouting. Today, engineers commonly refer to the guidelines proposed by Houlsby [3], which can be summarized as indicated in Table 2. In the same table also some typical ranges for allowable hydraulic gradient allocated to different dam types are given.

It is obvious that the highest hydraulic gradients in the rock mass occur in the contact zone at the dam foundation. In the treated zone they diminish with increasing distance from the dam rock mass contact surface at the foundation. Both, the recommended Lugeon and typical allowable hydraulic gradients as listed in Table 2 refer therefore to the zone close to the dam rock mass interface in the central foundation part. With depth corresponding less stringent values (i.e. higher Lugeon and lower gradients) might be acceptable.

These values are obviously intended for guidance only and their appropriateness must be reviewed and verified individually for each project in terms of the project-specific risks. To arrive at an appropriate value, It is important to identify the possibility of encountering particular features and peculiarities of the site by means of thorough geological and hydrogeological investigations, and to evaluate their influence on the permeability on a short and long term. If permeability and geological conditions on one site are highly variable, certain generalizations are necessary.

Relevance of additional testing - pre-injection and post-injection

The determination of permeabilities is essential both to justify the need for grouting, and to evaluate the success of the works executed. Thus, water pressure tests should be performed in exploratory primary holes before grouting and in check holes after completion of grouting in a certain section. These tests are required to compare the initial and the final permeabilities of the rock mass and to assess in this way the grout efficiency and success, respectively.

On the other hand, the execution of pre-injection water pressure tests in individual grout stages during the grouting programme, is not generally necessary, and might negatively affect the already treated rock mass. In addition, such tests during the injection works may not be representative, since there is no direct and/or consistent relation between the penetration of grout and that of water in a rock mass. As shown in Figure 7, a unique wide crack (A) may give the same Lugeon value as a high frequency of fine joints (B), while due to its binghamian rheology as well as the maximum cement grain size, the actual grout take might be much lower in the latter case.

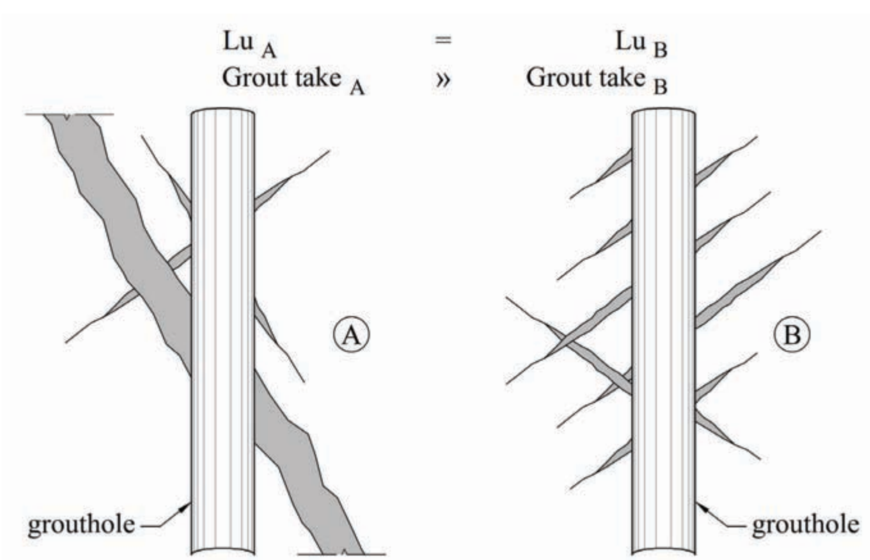


Figure 7. Difference in Lugeon values and grout takes for different fissures.

This is why water pressure tests do actually not give any indication on the actual grout takes to be expected. The only reliable way to obtain information on the actual groutability is therefore by the grouting process itself, which should show a consequent pressure increase and volume reduction from stage to stage. The use of Equivalent Lugeon analyses can substitute for pre-grout tests in a given stage, and provide intermediate data on the progress and effectiveness of the grouting programme. For the determination of the actual fissure conditions, that is especially their aperture with reference to the situation shown in figure 7, a complementary inspection by a borehole camera provides important information and is therefore highly recommended.

With the GIN method it is not the Engineer that defines the final pressure, but it is the rock, with its localized (stage) fissured status that decides what will be the final pressure to be reached.

Therefore, water pressure tests before and again after grouting the grouting programme, are allowed and even recommended, in order to evaluate the success of the performed injection works, in terms of the final permeability conditions achieved. To give a true indication of the residual rock mass permeability, post and pre-injection water tests must be executed at significantly lower pressures (normally equal to the predicted groundwater pressures in service) than the grouting pressures. Failure to follow this procedure will mean that the water tests will effectively be testing fissures which have not been affected by the grouting, and at pressures exceeding the service groundwater head, rendering the results un-representative.

In the upcoming Groutline issue (March 2016), the successful implementation of GIN grouting and other above mentioned design concepts in several challenging cases will be presented.

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As promised, below, some of my comments, as a strong supporter of the GIN method.

Being Europeans the authors of this articles, I think they didn't, in my opinion and correctly from their point of view, emphasize a very important point about the GIN method that, again in my opinion, is essential. With the GIN it is possible to use higher grouting pressures than the grouting pressures normally used in North America. Also today, and for important projects, I am reading Grouting Specifications where the grouting pressures are still evaluated with the "infamous" (in my opinion) "Rule-of-thumb" of 1 psi/ft (23 KPa/meter). Parenthesis. [Talking one moment about the "Rule-of-Thumb" (expression still used in our industry), my question is; how Engineers, as we are, can use a "rule-of-thumb" criteria? Are we Engineers or magicians? With all the respect for the magician. Will you be comfortable going to the 54th floor of a high rise building built by a structural engineer with rule-of thumb criteria?]. Close parenthesis.

With the GIN method it is not the Engineer that defines the final pressure, but it is the rock, with its localized (stage) fissured status that decides what will be the final pressure to be reached.

The article gives, additionally, a good approach to use and values of what should be the "consistency" of grouting flow.

Another point that I would like to emphasize is that with the GIN method we can have a better characterization of the status of the rock mass keeping constant as many parameters as we can; specifically flow and grout mix. We avoid consequently, for instance, fictitious "termination criteria" due to change of grout mix, thicker.

Interesting to hear some comments also from you, if any!

As usual, I make the same request, asking you to send me your grouting comments or grouting stories or case histories. My coordinates remain: Paolo Gazzarrini, *paolo@paologaz.com*, *paologaz@shaw.ca* or *paolo@groutline.com*.

Ciao! Cheers!

Prediction of rainfall runoff for soil cover systems: A laboratory approach

Ahlam Abdulnabi

Introduction

For the past few decades, soil cover systems have proven efficiency as engineered barriers to manage hazardous mine waste. The purpose of these covers can vary, but usually aims to restrict water and oxygen contact with sulphide minerals in waste rock and tailings, thus preventing the onset of Acid Rock Drainage.

The different types of soil covers and the factors considered in their design are summarized in O'Kane and Wels (2003) and the GARDGuide (The International Network for Acid Prevention (INAP) 2009). These types can be broadly classified into water covers and dry covers, which can be subcategorized as 'conventional low hydraulic conductivity' covers, 'capillary barrier' covers, and 'store and release' covers.

Generally, the design of dry covers is governed by the amount of net infiltration into the system. Prediction of said net infiltration requires a detailed soil-atmosphere modelling using site-specific infiltration models. Attaining accurate results from these models involve proper calibration using water balance equations. Thereby, necessitate the accessibility to runoff predictions, since surface-runoff can be the largest component of the water budget that directly influences the amount of net infiltration.

Prediction of rainfall runoff is particularly crucial not only for the design, but also for the longevity assessment of dry cover systems. Current methods of rainfall runoff prediction entail either complex modelling of infiltration at the point scale (Green and Ampt 1911; Horton 1939; Philip 1957; Mein and Larsen 1978); or require estimates prone to inevitable temporal and spatial variations in soil properties and rainfall events at the watershed scale (Schmocker-Fackel et al. 2007, Benson, 2010 and Jubinville 2013). Reliable models for predicting surface runoff at the field scale based on quantifiable soil properties seem, by and large, scarce, and require improvements especially when it comes to taking different initial state or antecedent moisture conditions of the soil into account (Abdulnabi 2015).

Since nothing beats repeatable verifiable observations, a laboratory-testing program was established to address this need for a reliable model to predict rainfall runoff for soil cover systems. The program investigates the correlation between laboratory-induced rainfall of different intensities, and the subsequent runoff response in both 'low hydraulic conductivity' and 'capillary barrier' soil covers. The primary focus of that program is to identify the appropriate variables that control runoff generation for both saturated and unsaturated state.

Description of the laboratory program

The laboratory program was conducted using a specially designed rainfall simulator apparatus. The main components of the apparatus were a water circulation system, a spraying system, and a flume to accommodate the soil and the measuring devices. The water circulation system consisted of a water reservoir equipped with a submersible constant-rate pump to direct the water to the spraying system.

The spraying system comprised of a number of nozzles of different orifices. Each set of nozzles produced different rainfall intensity. The most appropriate type of nozzles for this study was the one that provides an even distribution of medium-sized raindrops throughout a rectangular spray pattern. The height of the spraying arm was obtained by iteration trials to achieve the correct spray pattern, the optimum rainfall coverage of the plot, and the maximum uniformity of simulated rainfall. Similarly, the spacing between the nozzles was also obtained to eliminate overlapping of raindrops and to ensure concordant coverage of the plot.

The soil was accommodated inside a transparent flume to enable observing the wetting-fronts propagation as tests progressed. The dimensions of the box were 900mm in length, 300mm in width, and 350mm in height. The flume had a runoff collection outlet at the top, and a one-inch drainage opening at the toe. Measuring devices included Time Domain Reflectometry (TDR) probes and Tensiometers for measuring volumetric moisture content and matric suction, respectively. Instruments were distributed evenly at two elevations in the flume. A view of the overall setup is illustrated in Figure 1.

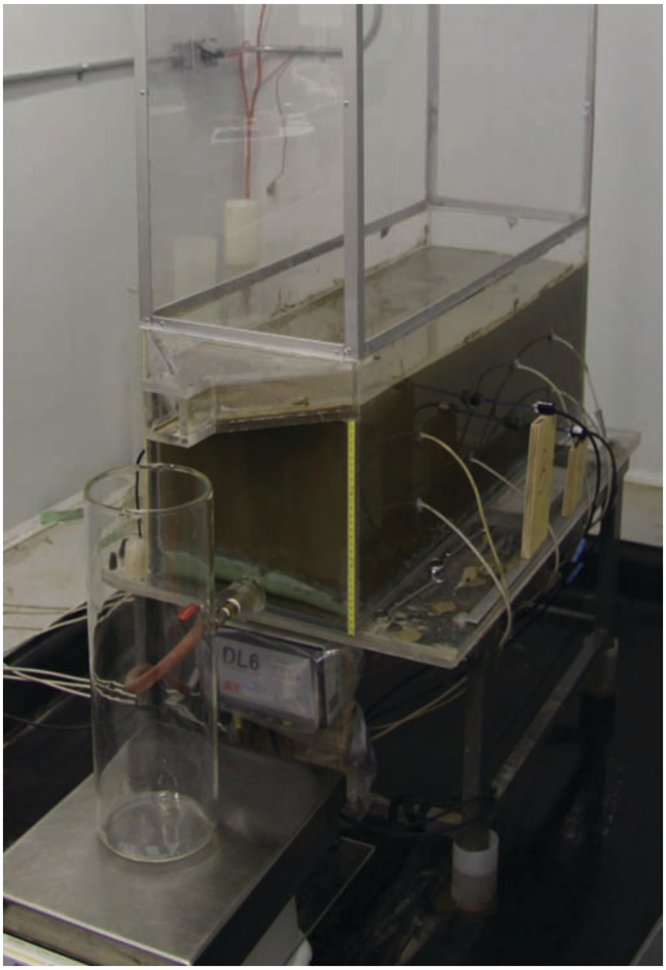

Figure 1. A view of the overall laboratory setup depicting a uniform layer of saturated silt.

Materials and methods

The testing program investigated the rainfall runoff response of two types of soil cover systems, namely low hydraulic conductivity and capillary barrier covers. The low hydraulic conductivity covers were represented by a layer of Devon silt 300mm thick. The capillary barrier covers consisted of a layer of Devon silt 150mm thick overlaying another 150mm thick layer of Suncor Tailings Beach sand.

A specially designed funnel was employed to pluviate the soil into the flume. Placement of soil was performed by initially placing the spout of the funnel at the bottom of the flume. The funnel was filled with soil, and then slowly raised along the flume's axes of symmetry. This placement procedure ensured that the soil was deposited in a low-energy state without any drop height. The velocity of raising the funnel, which controlled the density of the soil profile, was maintained the same by employing a mechanical movement when lifting the funnel.

The testing criteria for each type of cover system involved the application of six rainfall intensities ranging between 40-260 mm/hr for three days duration (eight consecutive hours each day). Testing considered two each initial state of saturation. Table 1 summarizes the different testing stages and controlling parameters. During each test, rainfall and runoff volume and rate were measured simultaneously in 15-minute increments. In addition, the volumetric moisture content and matric suction were recorded at two-minute intervals. Plots of volumes and rates of water balance components versus time were thereof established.

Table 1 Stages and controlling parameters of the testing program.

		Stages and duration of the tests					
Cover type	Initial state	I 40 mm/hr	II 55 mm/hr	III 90 mm/hr	IV 140 mm/hr	V 190 mm/hr	VI 260 mm/hr
Low hydraulic conductivity (silt profile)	saturated	55 hrs	33 hrs	33 hrs	130 hrs	80 hrs	33 hrs
	unsaturated	55 hrs	103 hrs	103 hrs	33 hrs	33 hrs	33 hrs
Capillary barrier profile	saturated	103 hrs	55 hrs	55 hrs	33 hrs	45 hrs	33 hrs
	unsaturated	103 hrs	55 hrs	55 hrs	55 hrs	55 hrs	55 hrs

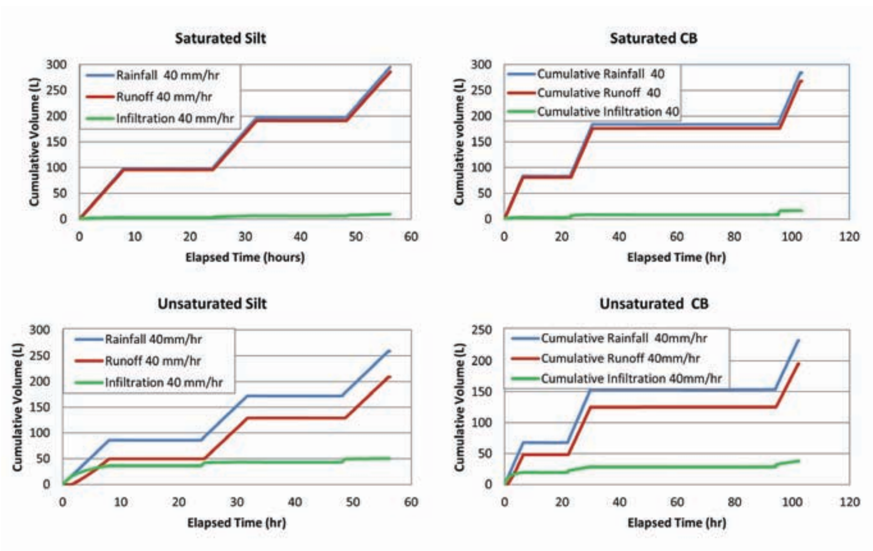

Figure 2. Typical measured components of water balance versus time in the saturated silt profiles (top left), saturated capillary barrier profiles (top right), unsaturated silt profiles (bottom left) and unsaturated capillary barrier profiles (bottom right) at 40 mm/hr rainfall intensity.

Results and discussion

Water balance

Typical measured components of water balance versus time are presented in Figure 2. In the saturated silt profiles, results suggest that about 95%-98% of the entire applied rainfall volume eventually converted into runoff with very little infiltration. Akin observations were made in the saturated capillary barrier profiles, although with higher infiltration at higher applied rainfall intensities.

Naturally, lower percentages of runoff, and higher infiltration were observed in the unsaturated profiles. In the unsaturated silt profiles, between 60-80% of the applied rainfall eventually converted into runoff. The increase in runoff percentage was found to be directly proportional to the increase in precipitation rate.

In contrast to the unsaturated silt profiles, higher percentages of runoff were observed in the unsaturated capillary barrier profiles. Measured cumulative runoff volumes ranged between 70%–80% of the overall applied rainfall. Similarly, the increase in runoff percentage was directly proportional to the increase in precipitation rate.

Rate statistics

Typical variation in rainfall, runoff and infiltration rates with time are illustrated in Figure 3 In the saturated silt profiles, the infiltration rate remained virtually unchanged as time progressed during each test, as long as the applied rainfall intensity remained constant, indicating a single soil property controlling the infiltration, thus runoff in the saturated profiles scenario. This observation proved true in all of the experiments of various precipitation rates. Increasing the applied rainfall intensity marginally increased the infiltration rate. Similarly, the runoff rate remained constant with time throughout each test, and demonstrated an accordant increase with the increasing applied rainfall intensity. This amounts to runoff being controlled primarily by the applied rainfall intensity and the saturated hydraulic conductivity of the soil for the case of saturated soils.

Conversely, in the unsaturated realm, the infiltration rate decreased non-linearly with time in both silt and capillary barrier scenarios in a consistent manner with the infiltration capacity function of the soil. The runoff rate followed suit though in an inverse path, where it increased non-linearly with time during each test, and increased from one set of tests to the other in accord with the increase in applied rainfall intensity. This suggests that the controlling parameters in the case of unsaturated soils are the applied rainfall rate and the infiltration capacity of the soil.

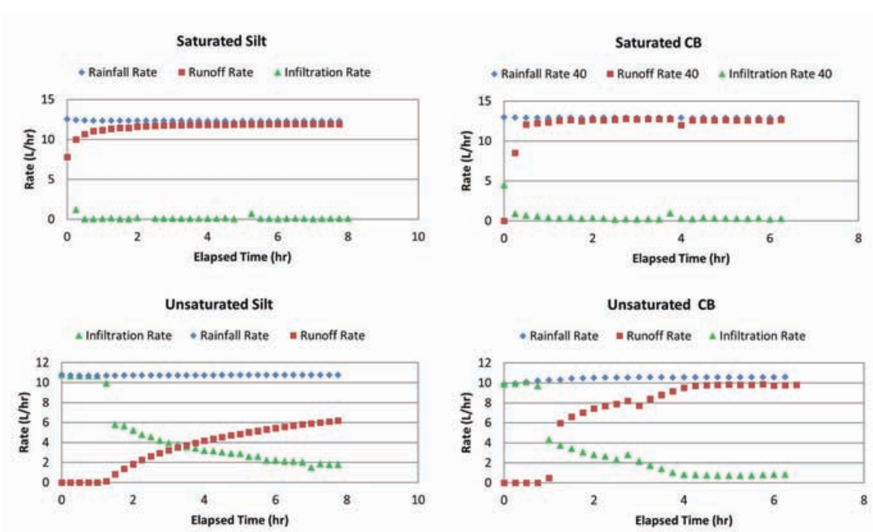

Figure 3. Typical measured rate of precipitation, runoff, and infiltration versus time in the saturated silt profiles (top left), saturated capillary barrier profiles (top right), unsaturated silt profiles (bottom left) and unsaturated capillary barrier profiles (bottom right) at 40 mm/hr rainfall intensity.

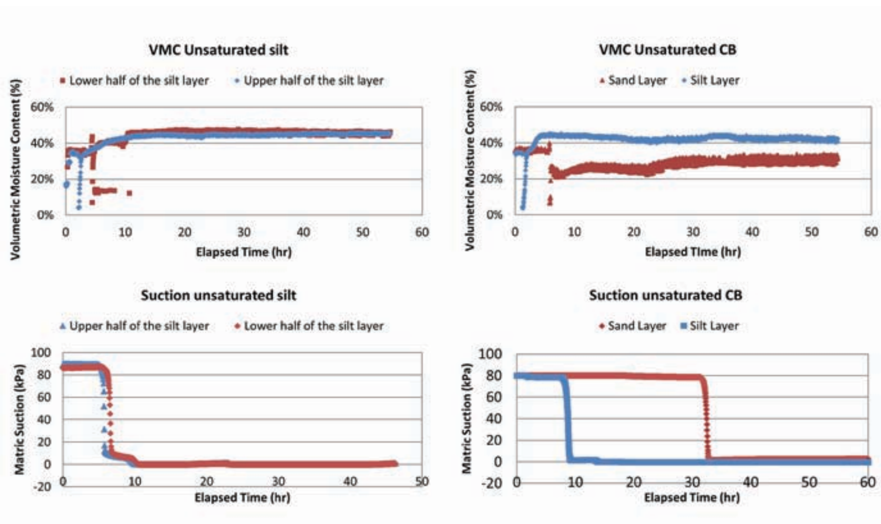

Figure 4. Typical variation in volumetric moisture content and matric suction profiles in the unsaturated silt (left) and unsaturated capillary barrier profiles (right) at 40 mm/hr rainfall intensity.

Changes in volumetric moisture content and matric suction

Typical measured changes in volumetric moisture content and matric suction as a function of time illustrated in Figure 4 demonstrate the distinct pattern of the capillary barrier effect. Remarkable time delay was systematically observed in the readings of moisture and suction in capillary barrier profiles, when compared to their silt counterparts exposed to the same rainfall intensity. Even more compelling confirmation was acquired upon inspecting time lapse videos, showing hydraulic impedance of wetting front propagation at the interface in the capillary barrier profiles illustrated in Figure 5. Results at higher rainfall intensities suggested lesser efficiency of the capillary barrier system in the form of shorter time delay for the wetting front propagation, and higher overall infiltration.

Conclusions

Surface runoff can be the most critical component of the water budget that directly influences the amount of infiltration into soil covers systems, thus controlling their design. Yet little do we know about prediction of such an important component of the water balance equation. A laboratory program was initiated to address and mitigate this issue. The chief focus of said program was to quantify the rainfall runoff phenomenon in a controlled laboratory environment for different cover types, saturation state scenarios, and different rainfall intensity settings.

In brief, a number of points stood out among the results of the laboratory programs. Runoff rates in saturated profiles behaved in much the same way as we expect them to, and proved to be dependent solely on the applied rainfall intensity and the saturated hydraulic conductivity of the soil. This is part and parcel of the fundamental understanding of saturated soils mechanics. Water can only infiltrate at a maximum rate i.e. the saturated hydraulic conductivity of the soil. Hence, when introducing a rainfall intensity that exceeds that limit, a portion of the applied water infiltrate and the remainder converts into runoff. By this account, the two primary parameters controlling runoff onset in saturated profiles are established.

By the same token, that upper bound of infiltration also exists in unsaturated soils in the form of the infiltration capacity function suggested by Horton (1939). The logic behind this runs as follows: as long as the introduced rainfall does not exceed the infiltration capacity function, the entire applied rainfall infiltrates into the soil. Conversely, once the applied rainfall exceeds the infiltration capacity of the soil, runoff transpires. This has been observed consistently in all unsaturated profiles, where initially the entire applied rainfall infiltrated, and then the infiltration rate decreased non-linearly with time in a comparable manner to the infiltration capacity function.

The splendor of capillary barrier covers was also demonstrated as a part of the results. Clearly proving how capillary barrier profiles exhibit higher runoff volumes compared to low hydraulic conductivity profiles exposed to the exact same conditions. This is attained by limiting the downward infiltration considerably due to the contrast in hydraulic properties of the capillary barrier materials, and therefore lowering moisture storage in the coarse layer. Moreover, the capil-

Figure 5. The wetting front propagation at the same point in time in the silt profile (left) and the capillary barrier profile (right) when exposed to the same rainfall intensity.

lary barrier performance was found highly dependent on the rate of rainfall for high rainfall events.

The quantitative results consistency and adherence to fundamental theories in saturated and unsaturated soil mechanics is compelling. The premise to instigate a new technique to predict surface runoff based on simple measurable soil properties and rainfall data, or by the very least improve existing strategies is valid. Additional research to formulate such technique employing laboratory data and numerical simulations is currently underway.

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This article was just presented to the Geotechncial Society of Edmonton. The Author was chosen as the Recipient for the 2015 Morgenstern Award by the GSE.

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Jonathan Fannin, Editor

Professor of Civil Engineering, University of British Columbia

Jonathan Fannin

In gathering my thoughts for the content of this column, it is a pleasure to reflect on the steady progress of the Technical Committees of the International Geosynthetics Society (IGS TC). The IGS is a learned-society dedicated to the scientific and engineering development of geosynthetics, with over 3,000 individual members and more than 150 corporate members. In reflecting on the role of such a learned society, I am reminded of the words of John F. Kennedy who, in a speech at Harvard University in 1956, observed it to be a place *"whose whole purpose is dedicated to the advancement of knowledge and dissemination of truth"*. Learned societies, like the IGS, can and indeed should aspire to a similar purpose.

The IGS technical committees were created under the leadership of Jorge Zornberg as IGS President, at the 9th International Conference on Geosythetics, in 2010. They were created to improve communication amongst members with specific technical interests and, in so doing, build upon the generally high level of technical excellence that is evident in the IGS-sponsored conferences proceedings, short courses and journals. The mandate is to address technical issues on which progress can be made, and findings disseminated, through the collaboration of an international group of researchers and practitioners. In principle, they operate by facilitating communication between members and with the geosynthetics community at-large.

IGS Technical committees

The technical committees provide a forum for refinement and exchange of knowledge in each of the following applications:

- Technical Committee on Barrier Systems (TC-B), which was tasked initially with centralizing a number of activities in the subject of waste and liquid impoundments
- Technical Committee on Filtration (TC-F), first conceived with a focus on filtration, in recognition of the very successful series of Geofilters conferences that were organized in the period 1992 to 2004
- Technical Committee on Soil Reinforcement (TC-R), originally intended to build on the successful activities of the former TC9 of the International Society of Soil Mechanics and Geotechnical Engineering (ISSMGE)

A fourth committee has been newly-created:

- Technical Committee on Hydraulic Applications (TC-H), with interests that encompass drainage, erosion control, and coastal protection.

Three of the committees convened recently at the XVI European Conference on Soil Mechanics and Geotechnical Engineering that was held at Edinburgh in September 2015. I take this opportunity to report on the activities of those committees at the conference.

Please share this article with colleagues and professional contacts using geosynthetics, who may wish to contribute to the success of the IGS Technical Committees.

The TC-B is chaired by Kent von Mauberge (Austria). A growing focus of the committee is to disseminate information to government agencies and regulators, and the committee is developing a strategy to distribute published conference papers of interest through the IGS and its respective chapters. These efforts are being made in tandem with promoting technical sessions on the subject of barrier systems at upcoming conferences, at both the national and international level. The TC-B is currently developing an information leaflet that describes best actices. A companion effort is underway, for which participation is invited from interested individuals, on barrier systems in mining applications and also in coal ash disposal.

The newly-formed TC-H is chaired by Pietro Rimoldi (Italy). It held its inaugural meeting at Edinburgh, where discussion addressed a number of topics including the potential for workshop organization, white papers, and a summary compilation of regulations in various countries. I expect that, in many regards, it will develop in a manner similar to the other committees.

The TC-R is chaired by Gerhard Bräu (Germany). The committee held a pre-conference 1-day workshop which address two thematic topics, namely that of research on soil-geosynthetic interaction and that of national approaches to regulation of design practice for reinforced slopes and retaining structures. The morning-session was devoted to presentations on soil-geosynthetic interaction, with several presentations on characterizing and modelling pullout resistance, and considerable emphasis on the response of geogrids. The afternoon-session had, perhaps unsurprisingly given the location, a strong European emphasis, with presentations on design practice in the United Kingdom, the Netherlands, France, Germany, Finland, and Italy, along with a Japanese presentation to bring a truly international perspective.

The TC-F, chaired by Kelvin Legge (South Africa), did not hold a meeting at the Edinburgh conference. It has, however, been active in location organising short courses, training lectures and/or keynote lectures at the GeoAmericas 2012 conference, and the 10th International Conference on Geosynthetics. Of particular note has been the effort coming out of South Africa to revisit the International Commission on Large Dams (ICOLD) Bulletin 55 that was published, in 1986, on the subject of geotextiles as filters in dams - with the objective of rewriting in order to disseminate much of the new technical insights that have been gained over the elapsed period of 30 years! To inform future efforts of the TC-F, a survey questionnaire was placed on the IGS website that solicited more than 200 responses from those working on the subject across the world.

In my opening statement, I alluded to the steady progress of the IGS technical committees. Much of the work of these committees and their members remains largely unseen, and indeed I have sought only to mention some of their efforts - however the benefits manifest themselves in many and varied ways, as technical information is compiled and disseminated by the IGS, both for its membership and for the geosynthetics community at-large.

The JFKennedy quotation is taken from: http://www.jfklibrary.org/Research/Research-Aids/Ready-Reference/JFK-Quotations/Harvard-University-Speech.aspx

GEO-INTEREST

An engineer's liability extends beyond his client to the ultimate owner - Case History IV

extract from Suit is a Four-letter Word

(Hugh Nasmith, 1986)

Hugh Nasmith has put together an excellent book on litigation which is easy to read, covers the litigation scene thoroughly, has subtle humour, and most important of all, is umderstandable. He remarks in the opening paragraphs that experienced geotechnical engineers will find nothing new in the book except comfort that their situation is not unique. This is true but experienced engineers should read it anyway. (From a review by William A. Trow).

A geotechnical engineer may feel that when he is employed as a sub-consultant on a job the prime consultant is responsible for properly using his advice and where necessary passing that advice on to the client. The following case illustrates the fallacy of this assumption.

The client in this case was an elected public body who was responsible for providing a building to house staff and facilities to serve the community.

The prime consultant was an individual architect who had worked closely with the client over a period of years and was a member of the committee responsible for selecting a site for the building. The architect had designed and supervised the construction of other buildings for the client near the proposed new building. The architect had a standard contract with the client to provide services and supervision of construction for the proposed building.

The sub-consultant was a small firm of consulting engineers engaged principally in the field of structural engineering. From time to time they had worked with the architect to provide minimum structural design which the architect incorporated in his drawings.

The architect arranged with the client to provide a backhoe to dig two test pits on the site and called the structural engineer to send someone out to inspect the test pits. The structural firm employed, on a part time basis, a retired engineer whose expertise was principally in structural design but who had some practical experience with soils though he made no claim to be a geotechnical engineer.

This employee of the structural firm met the architect on the site and inspected the test pits. He correctly described the soil that was exposed in the test pits and suggested a bearing capacity for the soil. He also told the architect that he felt that deep borings and a proper geotechnical evaluation was required. The architect replied that the client would not be prepared to pay for such an investigation.

The employee reported his observations and comments to one of the principals of the structural firm who phoned the architect and was again told that the client would not pay for deep borings and a proper geotechnical study. The structural engineer then asked what bearing value he should use in the design and the architect responded with a conservative value which he said that the client had provided. On this basis the structural firm proceeded to design beams, columns and footings for the building.

During the subsequent court proceedings both statements were denied by the client who said that the architect had never asked for a deep foundation study and had never been given a recommended bearing capacity. At the time however the structural engineer had no reason to doubt these statements, particularly since the client had technical expertise on his staff and had experience with other buildings in the area.

Shortly before the contract for construction of the building was let, the client asked the architect for a copy of the soils report. The structural engineer with some indignation told the architect that he should know there was no such report. The architect replied that all the client required was a description of the soils exposed in the test pit and he confirmed this request in a letter to the structural engineer. The employee engineer of the structural firm wrote a letter describing the soils exposed in the test pits and gave an estimate of the bearing capacity. However, his letter did not include a recommendation for deep borings and a proper foundation study.

At the same time that the soils report was requested the client asked the architect to obtain a form letter from the structural engineer certifying that the building was designed according to the requirements of the National Building Code. The structural engineer provided the letter as requested.

The building was built according to plan and shortly after completion showed serious signs of distress. Various alternative explanations were considered and substantial amounts of money were spent in an effort to correct the problem. However, it was clear that the problem stemmed from an inadequate foundation design.

The client sued for damages against the architect, structural engineering firm and the contractor. The litigation was extended and complex. The contractual relationship and responsibilities of the various parties were explored in detail. The case was appealed to the Provincial Court of Appeal and finally to the Supreme Court of Canada.

The contractor was found to have no liability. The architect and the structural engineering firm were found to be jointly and severally liable for the losses suffered by the client. The liability was assigned 60% to the architect and 40% to the structural engineer. However since the architect did not carry any professional liability insurance the entire burden of the losses fell on the structural engineering firm and his insurer.

The architect was found liable because he failed through negligence to fulfill the terms of his contract with the client.

The court concluded that the engineer did not have a contract with the client but he was found liable in tort to the client. The two actions which the court regarded as significant in the decision were:

The soils report which the structural engineer provided failed to estimate settlements in deep soil layers or recommend deep borings.

The form letter stated that the design met all the requirements of the National Building Code. The code requires that for a building of this size the foundation design must be based on a subsurface investigation by a person competent in the field of soil mechanics, or alternatively, be based on local practice including succesful experience with similar buildings and soils in the adjacent area.

Even with the benefit of hindsight there are only a few points at which the structural engineer might have been expected to act differently so as to minimize the risk of things going wrong.

Within the practicalities of the consulting business, it isn't realistic to suggest that he should have refused the assignment. He could only do this if at that time he had such a low opinion of the competence and honesty of the architect that he preferred to forego all future opportunity of paying work with this client.

However, if a letter report on the inspection of the test pits had been written to the architect immediately after the inspection, it would probably have included a recommendation for deep borings and a proper geotechnical study. By the time the letter was written just before the contract was to be let, the lack of a proper geotechnical study was a fait accompli and the engineer would feel a great deal of pressure to avoid causing delay and friction by raising this topic which so far as he knew had already been settled by the client.

The structural engineer also assumed more responsibility than he should have in signing the form letter stating that all provisions of the National Building Code had been met. In signing this form letter the structural engineer probably felt that he was only referring to the structural aspect of the Building Code while in reality he was taking responsibility for all aspects of the building including those related to foundation design. The structural engineer should have limited his approval only to the portions of the Building Code which applied to his structural analyses.

SRK Launches 40th Anniversary Book *SRK: 40 Years in the Deep End*

SRK Consulting hosted a party for the Vancouver launch of its new book *SRK: 40 Years in the Deep End*. Employees past and present reminisced about the company's evolution and celebrated its achievements. Distinguished guests included cofounder Andy Robertson and other influential consultants from SRK's early years such as Keith Robinson, Jack Caldwell, Ian Hutchison, and John Gadsby. The book tells how SRK was established in 1974 to fulfil a need for technical consulting services in Johannesburg, South Africa. Although the founders were experienced engineers, starting a new consulting practice required a leap of faith into the deep end of the mining world. Tackling each project with enthusiasm, they quickly built SRK into a force to be reckoned with.

During the subsequent 40 years, SRK consultants have continued to approach mining and exploration challenges across the globe with energy and commitment. "The metaphor of jumping into the deep end is therefore a fitting theme for the book's cover and narrative," said Andy Barrett, global and North American president of SRK.

In addition to describing the evolution of SRK's offices around the world, the book provides insight into SRK's philosophies and what makes the company unique. Interviews with about 160 of the few thousand people that SRK has employed over the last 40 years yielded many memories and anecdotes that convey the spirit of the organization. These stories also exemplify the main reason for SRK's success: the commitment of its staff.

"This book is a tribute to the people whose talents, passion, and four decades of hard work have built SRK into a respected resource industry consultancy," said Barrett.

A limited number of copies of the book have been printed and an e-book version will be available by the end of 2015.

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