Introduction by John Dunnicliff, Editor

This is the 85th episode of GIN. Four articles this time, together with two discussions of an article in the previous GIN, and the authors' closure

The fundamentals of vibration monitoring - things to consider

During the monitoring course in Italy last June, Bob Turnbull of Instantel made an excellent presentation about vibration monitoring. Here's a written version.

Specifications for robotic total station field work

The previous GIN included an article by Douglas Roy and Jonathan Stuhl of GZA GeoEnvironmental about specifications for robotic total station field work. Here are two discussions of the article, by Martin Beth of Soldata and Joel Volterra of Mueser Rutledge Consulting Engineers, together with a closure by the authors.

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

The previous GIN included an article about instrumentation for braced excavations, and I said that similar articles for other project types would follow. Here's one about embankments on soft ground.

Symposia on Field Measurements in Geomechanics (FMGM).

This episode of GIN includes two articles by Andrew Ridley of Geotechnical Observations Ltd. The first is a report on the Ninth FMGM, held in Sydney, Australia in September 2015. The second is about the future of FMGM.

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

The Third International Course on Geotechnical and Structural Monitoring (www.geotechnicalmonitoring.com) will again be held in the historic location of Poppi (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). During the field trip more than 20 leading companies will present their monitoring systems in a dedicated exhibition area.

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

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*

Get a dog up ya! (From a website about toasts: "Apparently an Australian expression which really doesn't mean anything much at all. Often said whilst being drunk and yelled at high volume at the footy"). Being uncertain about the political correctness of this toast, I asked an Australian colleague. He said "GO!"

The fundamentals of vibration monitoring - things to consider

Bob Turnbull

Applications for vibration monitoring

Vibration monitoring covers a very wide range of applications. When you consider that anytime something moves it creates a vibration, the question really becomes, is the vibration relevant to your application? If we consider vibration in terms of geotechnical and structural monitoring then we can break the vibration sources into two broad categories, natural and man-made vibrations. As we all know natural sources of vibration like earthquakes, volcano, landslides, avalanches and even the weather can be devastating to people and structures. These types of events provide very little warning before they happen and therefore are very hard to predict. On the other hand, man-made vibration sources like construction activities, blasting, mining, pile driving, dynamic compaction, tunneling, train and vehicle traffic and people are quite easy to predict.

Main goals of vibration monitoring

When it comes to vibration monitoring the main goals are to protect people and assets. The more we monitor the better we understand how these vibrations impact our lives. Monitoring natural events helps us improve our predictive models and possibly take action sooner to reduce their effect on people. It also helps us understand these forces which can then be used to help improve our structural designs and construction activities. The monitoring of man-made vibrations will also help protect people and improve our construction activities. However, in many countries around the world there are also legal limits that have been established for man-made vibrations. These limits are generally set to reduce the vibrations that might have an effect on people and to prevent damage to a wide range of structures. This article will focus on the monitoring of man-made vibrations and present some of the different aspects of vibration monitoring that should be considered.

Things to consider

Vibration limits

Before starting any project you must first understand what the vibration limits are. The vibration limits will provide key information on the type of sensor that should be used on your project. Many countries have developed their own general vibration limits, however some stakeholders of the project may choose to implement even stricter limits.

To make sure you understand the vibration limits of your project, you will need to answer at least four questions:

1. Will you be measuring velocity, acceleration, displacement, strain or decibels?
2. Will these measurements be peak or RMS values?
3. What dynamic range is required for the sensors?
4. What is the frequency range to be monitored?

Choosing the sensor and data logger

Many software programs today provide tools to convert back and forth between velocity, acceleration and displacement or to calculate strain and display results in decibels based on a reference level. Whether you choose a geophone, an accelerometer or some other sensor you will need to make sure the data logger and software package will be able to convert the data into the desired units. If you choose a geophone and need to report the results in acceleration you will need to differentiate the velocity results to obtain the acceleration. If this is a manual process and you have thousands of events to convert, it might be better to choose an accelerometer to start with. Whatever sensor you choose make sure the data is recorded with enough resolution to be able to convert the results to the desired units with an adequate resolution.

When choosing a sensor make sure it has the dynamic range, resolution and frequency response to meet your requirements. Choosing a 500g accelerometer with a 3000 Hertz (Hz) frequency response may not make sense if your limits are 40g and 750 Hz. Generally, you will want to select a sensor that has a dynamic range and frequency response that are slightly larger than your requirements. If your limits were 40g and 750 Hz then select an accelerometer that has a range of 50g and 1000 Hz response. Once you have a sensor in mind make sure the data logger can provide the resolution you need. The resolution will be based on the analogue to digital convertor (A/D) that is used in the data logger. This can often be found on the data sheet for the data logger. If the data logger had an 8 bit A/D the best resolution it could provide for a 50g accelerometer would be 0.2g (50/(2^8). If the data logger had a 16 bit A/D the resolution could be as small as 0.00076g.

What is being monitored?

Now that we understand the vibration limits and type of sensor we need, we now need to understand what is being monitored. This will help to determine how and where the vibration sensors can be installed. Monitoring a building is very different from monitoring a stained glass window in the building. There are several methods of installing the sensors, the most reliable being to attach the sensor directly to the structure being monitored. However other methods like burying the sensor in the ground next to the structure and sometimes coupling the sensor to a surface with sandbags can also be used. The main goal is to install the sensor in such a way that it will experience the same vibration as the structure that is being monitored and not decouple (move independently) from the structure. It is also important to understand, that if the sensor is attached directly to a structure, where it is attached can affect the results. Attaching the sensor in a corner will have a very different result to attaching it in the middle of the wall.

The International Society of Explosives Engineers (ISEE) have developed a "Field Practice Guidelines for Blasting Seismographs" that can be found on the Internet. This guideline contains useful information on the placement and installation of the sensors.

What frequency response do you need?

The type of structure being monitored will also help determine the frequency response and sample rates that are required. Generally, you will want to sample at least four times the highest frequency that is expected. This will help reduce any errors due to the sampling rate. The higher the sample rate the better the resolution in the data and the greater the accuracy in recording the vibration.

Public relations and reporting

The stakeholders are an important part of any monitoring program. Making sure they are kept informed will help the project progress as smooth as possible. Knowing who your stakeholders are will also help you produce reports that they can easily understand. Reports that are too technical or do not provide clear results will slow the project down as you may spend a lot of time answering questions. The vibration time history will be useful to a consultant but may raise a lot of questions for stakeholders. However, displaying the data relative to your project limits can help stakeholders understand the vibration they experienced. It will also help if the stakeholders have an understanding of how the project will progress. As an example, if the project included blasting then make sure the stakeholders know when you are planning to blast and where they might be able to watch. This will help reduce the "startle" effect of blasting. In general, people are a lot less likely to complain if they are kept informed.

Collection and distribution of event reports

The collection and distribution of event reports were once very labor intensive. People would have to go to the project site, set up the equipment, wait for the event to happen, collect the data, and then take it back to the office for analysis. The reports would then have to be generated and sent to the stakeholders. This could have taken days or weeks for the reports to get to the stakeholders. Now projects can be monitored 24/7 with the project data being collected automatically. As soon as the event happens, the data can be sent to the stakeholders immediately after it has been recorded. The data can also be posted on the Internet and even sent to the stakeholders' cell phones.

Closing comment

As vibration monitoring projects become more and more demanding, the need to understand the basics will still remain. Spending the time to make sure you select the proper equipment, that it is installed correctly, and that the reports are clearly understood by all of the stakeholders will help you achieve vibration monitoring results that are satisfactory to all.

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Discussions of "Qualifications of the robotic total station construction monitoring professional"

Douglas Roy and Jonathan Stuhl

Geotechnical News, Vol. 33 No. 4, December 2015, pp 30-33

Martin Beth

Thank you to the authors for pointing out some important elements in specifications for robotic total stations, in particular regarding the profile of the engineers and technicians involved in the installation and maintenance.

I would like to propose some elements of further reflection. These can be split into four parts, first addressing the RTS (AMTS) specialist, then the "by whom" question", then thinking about specifications key points, and finishing with some comments on figures 3 and 4.

The RTS (AMTS) specialist

The conclusion to the article proposes a typical text for the RTS specialist specification which clearly describes and restricts its role to designing, testing and operating the monitoring system, ensuring that the data is of high quality and provides real information to the Engineers. I agree 100% with this statement.

I therefore wonder why the last bullet point requests the RTS specialist to be a PE or a PLS?

In my opinion:

- A structural or geotechnical engineer should be in charge of defining what information should the measurement system provide, what are the alert criteria, what course of action to give when considering the monitoring results.
- The RTS specialist and/or the monitoring & instrumentation specialist should ensure that a system is put in place that provides results than can be efficiently used by the structural or geotechnical engineer.

- The need for PE or GIE stamp might apply to the structural or geotechnical engineer, within the United States tradition of protecting local borders. It certainly does not apply to RTS specialists, in my opinion.

I have another comment about the RTS specialist: Running a monitoring program with high quality results is so specific, even more so when using RTS, that I would recommend not experience of two projects, but ten if possible. Of course one wants to receive at least three offers, so a request for such extensive experience might be a little too drastic and could be reserved for large projects.

The "by whom" question

On the subject of the "by whom", I believe the key points are about procurement and the structure of the contract. Procurement must not be based on low cost, and it should target companies with experience and reputation, etc… By "structure of the contract" I mean the question of who the monitoring specialist works for: the main contractor, or the engineering firm, or the owner. All these points have been discussed in detail in previous episodes of GIN, so I will not repeat them.

Specification key points

If we think about the main items required to obtain good instrumentation and monitoring (including RTS) specifications, I would recommend:

1. Define clear objectives in terms of what engineering values are needed, with what precision and at what frequency. These objectives should be defined by a geotechnical or structural expert, to suit exactly the project needs, and no more no less than the project needs.
2. If possible, give liberty to the specialists to select the monitoring system that they will use to answer these objectives.
3. Define how the specification, and especially the precision, will be controlled. This is not an easy task, and could the subject of a complete paper. But it is absolutely necessary.
4. Insist on the fact that the specification will be enforced, and detail the contractual consequences of not matching the specifications.

Thinking about it, we are not far from the SMART theory: Define specifications that are Specific, Measureable, Achievable, Relevant, Time defined.

Some comments on Figures 3 and 4

Finally, I will finish with some minor technical comments about figures 3 and 4. Figure 3 appears (I am not 100% sure, as the vertical scale appears to be masked around 0, or highly non-linear around 0) to show some RTS data of fairly low precision, with a lot of noise and quite a few spikes. There can be many explanations for such data, such as a very complex measurement conditions, the total station far from the targets, or other such real-life difficulties. However I would not want readers to think this is the standard in RTS results. Maybe the cause can be found in the configuration shown in figure 4, where clearly it was not possible to achieve a proper topographic layout.

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Joel Volterra

Thank you to the authors for addressing a subject that I believe worthy of periodic reexamination and ongoing discussion. Before addressing the Professional Engineer (PE) versus Professional Land Surveyor (PLS) issue, I've added a few related matters that I believe factor into that very issue, hoping at the same time it doesn't cloud the issue. I've seen this discussion center on the role of the technician versus the role of the Engineer in undertaking the tasks which together comprise these complex instrumentation and monitoring programs, specifically including the now prevalent use of robotic total stations (RTS) or automated motorized total stations (AMTS).

Data interpretation requires knowledge of construction progress records

My and my colleagues' philosophy has been to minimize the separation of implementation, collection and data reporting from data evaluation and interpretation. Construction progress records are necessary for data interpretation and evaluation. In the writer's experience all too often the two are not submitted together, and thus acknowledging a designed-for or anticipated movement or lack thereof as a function of adjacent construction activity is lost. This undermines the value of the monitoring program as a whole and diminishes its intrinsic value of collaboration among owners, contractors and consultants undertaking the work, whether performed by a PE, PLS or a technician under direction of one of the former.

Who is best suited to evaluate data?

Where an engineering analysis or structural computation estimates


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:

- **Three sessions of professional presentation about new trends**
- **Two sessions dedicated to case histories, presented by selected registrants.**

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), 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.**

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½-inch of lateral building or excavation support movement, say during a cantilever excavation phase, are you more concerned if no movement is reported or if 5/8" of movement is recorded? The reporting of "zero" movement ***may*** be more indicative of a problem and result in raising a bigger flag to reassess the monitoring system stability and or data processing algorithm and suggest something is not working properly or according to expectations. Alternatively, 5/8" of reported movement while potentially alarming to one not familiar with the design analysis, ***may*** support that the structural engineer and monitoring team deserve praise for their deformation analysis and movement reporting, just 1/8" off from their estimate. Who is best suited to evaluate these possibilities?

The evolution of roles, sub-specialization

This discussion offers that a PLS may be as suitably trained to administer these programs as the PE. In the past before recent Codes and Specifications, the PE may have performed land surveying directly. This person likely played a prominent role in the design and construction inspection, and performed optical monitoring from the job site where physically aware of ongoing construction progress and activities, weather trends and other external factors which affect the adequacy of their recorded data. High or sudden vibrations or rapid temperature swings resulting in poor survey traverse closure and thereby increased error were marked with an asterisk as they were recorded or reported, as the evaluation was made concurrent with data processing by those familiar and trained in recognizing these occurrences. Potential to lose such observations occurs more frequently in automated data processing software algorithms and or those in which third party monitoring consultants perform their tasks independently from other trades.

Leading into the 1990s and to the present day on many smaller projects, the PLS generally provided the installation and as-built location of monitoring "points" plus periodic readings of delta x, y, z for interpretation by "others". The qualifications of the "others" varied widely, from owner, to owner's representative in the form of the general contractor or construction manager, to an architect or engineer likely specializing or sub-specializing in a different discipline.

- How qualified are those people to understand ground movements, building response and/or to recognize typical red flags indicating potential errant readings or system flaws, or true signs of movement versus scatter, or no reported movement despite large seasonal thermal variations?
- How intimate were these people to the anticipated ground or building response?
- How much did or does the risk of underestimating or under-recording or under-recognizing the amount of deformation movement matter, meaning what are the inherent project risks?
- Are such things addressed in the majority of boiler plate or recycled project specifications?

Technology and methodology has morphed into current practice, and the efficiency of increased monitoring frequencies has supported automation in hopes of achieving greater data quality. As movement trends were further defined by multiple readings per day or hour, the less frequent manual survey by PLS became less cost efficient comparatively. There seems to be a cross-over point at a frequency of about two to three readings per week at least in New York City, where monitoring systems generally become automated and the work scope shifts from PLS to PE (unless a PLS administers the automated system). A PLS two-person crew, at $1,800 per day with equipment and office support performed three times per week results in costs of about $5,400 per week or $23,000 per month. Over the course of several months, automation becomes preferable and cost efficient while realizing numerous other advantages over manual survey.

Affordable redundancy by Professional Land Surveyor

I advocate using a PLS to provide monitoring point as-built and thus licensed coordinates during the baseline monitoring period, and periodically throughout the work as a sanity check of an automated system. In monitoring projects of 4 to 6 months or longer bridging a seasonal change, a building is likely to respond by deforming through its maximum normal atmospheric drift or range as well, irrespective of adjacent construction activity. As introduced above, should automated readings suggests either zero movement or 5/8" of movement whatever the case may be, a re-survey of prisms by the same PLS and means and methods ***may*** be appropriate to verify the automated readings, or to flag that a more detailed review of one or both systems is warranted. Recognize it is plausible that seasonal thermal variation effects increase, decrease or cancel out construction induced movements over any particular time period, though it unlikely movement trends would align with environmental factors if that was the case, hence the need for good baseline data over a range of thermal conditions and frequent readings. These may be considered redundant readings, so cost implications factor into whether or when they are performed.

Collaboration among the morphing evolution of roles into subspecialties

Further sub-specialization of tasks and consultants (not only in survey or geotechnical disciplines but others as well) puts a higher level of ethical and technical responsibility on the part of the PE designing, specifying and or signing off on these programs or summary data or interpretive reports, whatever their background or title. Those likely most highly suited and positioned to perform, evaluate and interpret the monitoring programs and data remain are those who played a role in designing the structure on behalf of the owner, who ultimately has the most at stake to complete the project without incident or delay. We find that construction contractors are sometimes receptive to relinquishing the monitoring programs to the owner or the owner's consultants, allowing many other benefits such as starting the process of access, permissions, installation and baseline prior to awarding the construction contract.

On many projects, the cost and risks of today's monitoring programs rival those of the project's geotechnical investigation and or excavation support design. I believe that the assignment of specific tasks or roles in undertaking the geotechnical or structural monitoring program requires as much thought, premeditation and vetting at each stage of design and construction as does other major design and construction tasks. Should an "expert" not be engaged to directly manage the monitoring scope, roles and methodology, it is in the best interest of the design or construction team to consult one. It is unlikely in the writer's opinion, that a one-size fits all approach will ever be established, though local Codes may look to further pre-certify organizations to perform such "Special Inspection" tasks as a function of individuals and their respective firm's history and experience. I agree and support the author's recommendations for tasks to be incorporated into contract specification language for an RTS or AMTS specialist, following the lines that they have thought through assigning these roles, and also that the specifications be reviewed on a case by case basis by someone experienced in this type of work.

As the monitoring scopes and costs increase, responsibility may be more and more shifted from the designer to the PE who is charged with implementing and managing the program during construction. As always, the person signing off on the work must have a comprehensive understanding of the technical issues. Whether a PE with geotechnical or structural background or specialty, a PLS or someone with another title all together is charged to lead the program will continue to depend on the nature of the specific job and the philosophy of the firm awarded the work. However, it clearly behooves each to consult and collaborate with others holding relevant background and experience before undertaking the specified monitoring scope. Where the monitoring consultants are third party to the design, appropriate questions should be asked as to anticipated deformations and timing of those throughout construction, such that appropriate resources can be dedicated to evaluate the work as those time frames occur.

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Authors' Reply

We would like to thank both Joel and Martin for their in-depth discussion and John for his ongoing support of these discussions. We were remiss in also not acknowledging Charlie Daugherty who brought this subject to task for the authors and had long been involved in the resurgence of New York City tunneling instrumentation over the last 20 years.

Although our article was intended, and as John states in his introduction, **to guide owners, engineers and specification writers,** the topic is clearly a one of great passion and strong opinion for both Joel and Martin.

Martin Beth

Clearly Martin is a proponent of having highly qualified personnel, no matter what their education and/or certification by a government agency, to oversee (and ideally design) the data collection systems on instrumentation projects. Where this becomes difficult is for the specification writer to have some comfort regarding who will be qualified to undertake this work, accepting that they will in all likelihood have little say in who the general contractor selects, given that in the majority of large horizontal infrastructure project the work is a public bid.

The government agency certification of the PLS or PE gives the specification writer some assurance that the work will be undertaken by a qualified person, without providing a long list of qualification which the specification writer likely is not familiar with. In addition it was our intention to focus only on the scope of the RTS portion of the monitoring, to be completed as a subset of the overall monitoring system overseen by the Geotechnical Instrumentation Engineer. This brings up the argument that maybe the industry should pursue some type of internal RTS user certification, but this lacks support as Joel later discusses.

Regarding Martin's discussion of the specifications we agree and strongly support an enforceable specification that, in the end, levels the professional playing ground.

As for Martin's comments on figures, we agree that a large number of factors affect the precision of the RTS data in a real-life monitoring environment. Regarding Figure 3, the RTS was positioned well within the monitoring zone and with some less than ideal configuration for the monitoring targets. For example, the vertical angle and orientation was such that during daytime hours glare from the sun was an issue. Accepting the facts of the locations required to provide the monitoring, the precision of the data shown exhibits a standard deviation of approximately 0.035 inches. As the manufacturer's stated precision for distances measurement is 1 millimeter or 0.039 inches, the precision is within the parameters of the instrument. It has long been our view that extensive data-smoothing should not be employed on raw data used by the RTS specialist and the engineer should review the site conditions to determine plausibility of actual movement. It has also been our experience that after significant movements are experienced, as shown in the figure, the system precision may be slightly degraded as the original orientations of the monitoring prisms to the RTS has been changed.

Finally it is also important to discuss that, as Martin notes, Figure 4 does not provide a proper geometric layout for the RTS system. We feel it is important for readers to understand that some systems cannot be designed ideally. This figure presents a particularly challenging situation where monitoring was required over a long-span bridge across a body of water, which required extensive design to the system to improve the robustness of the data quality. We consider the design of the system in this figure to be a prime example of incorporating different backgrounds, skill sets and experience levels into the design of a monitoring system, and the complexity often required may not be found in a single easily defined individual.

Joel Volterra

Joel starts his discussion with a topic also brought up by Martin, and one we wanted to avoid, that the RTS specialist should be a technician. It was not our intention to discuss the qualifications of the Geotechnical Instrumentation Engineer or state that the monitoring system as a whole should be designed and overseen by the RTS specialist who we attempted to describe. Luckily we realign with Joel as he further goes on to discuss; depending on how the project is managed the data interpretation and data management should be undertaken by personnel that not only understand the reason for movement but the evolving technical nature of RTS data.

Again, it goes back to the argument that this work should be undertaken by a very small subspecialty of PEs or PLSs who have obtained, through project experience or formal training, the qualifications to undertake the work. This brings us back to the point regarding the requirement for having a licensed professional making this determination regarding their own qualifications regardless of the specification language.

Maybe the answer is that the specifications should be written by someone (PE or PLS) who has the same or similar project experience.

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General role of instrumentation, and summaries of instruments that can be considered for helping to provide answers to possible geotechnical questions. Part 2.

John Dunnicliff

Introduction

This is the second in 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.

Part 1, covering internally and externally braced excavations, was in December 2015 GIN.

Part 2 covers embankments on soft ground.

The following points were made in the introduction to Part 1, and also apply here:

- 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 is 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.

Embankments on soft ground

General role of instrumentation

This article relates to the use of geotechnical instrumentation where all the geotechnical questions are associated with the soft ground itself, and not with the embankment.

In many cases, selection of soil parameters for the foundation soil is reliably conservative. The embankment is therefore designed with confidence that performance will be satisfactory, and "comfortable" factors of safety are used. In such cases, many projects will proceed without the use of instrumentation. However, some uncertainties always exist. Where design uncertainties are great, factors of safety small, or the consequences of poor performance severe, a prudent designer will include a performance monitoring programme in the design.

Table 3. Some instruments that can be considered for monitoring embankments on soft ground

Possible geotechnical questions	Measurement	Some instruments that can be considered
What are the initial site conditions in the soft ground?	Pore water pressure	Vibrating wire piezometers installed by the fully-grouted method (Open standpipe piezometers) (Pneumatic piezometers)
	Vertical deformation	Conventional surveying methods Remote methods
Is the embankment stable?	Horizontal deformation	Conventional surveying methods Remote methods Inclinometers (In-place inclinometers)
What is the progress of consolidation of the soft ground?	Vertical deformation of embankment surface and ground surface at and beyond toe of embankment	Conventional surveying methods Remote methods
	Vertical deformation of original ground surface below embankment	Probe extensometers (Single-point and full-profile liquid level gauges) (Settlement platforms) (Horizontal inclinometers)
	Vertical deformation and compression of subsurface	Probe extensometers
	Pore water pressure	Vibrating wire piezometers installed by the push-in method

In spite of a long record of embankment construction throughout the history of civil engineering, embankments that are designed with a factor of safety greater than unity fail embarrassingly often. On the other hand, some test embankments that are designed to fail intentionally, never do. Thus, it is not surprising that instrumentation plays a significant role in design and construction of embankments on soft ground.

The most frequent uses of instrumentation for embankments on soft ground are to monitor the progress of consolidation and to determine whether the embankment is stable. If the calculated factor of safety is likely to approach unity, instrumentation will generally be installed to provide a warning of any instability, thereby allowing remedial measures to be implemented before critical situations arise.

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

Table 3 lists the possible geotechnical questions that may lead to the use of instrumentation for embankments on soft ground, together with possible instruments that can be considered for helping to provide answers to those questions.

Report on 9th Symposium on Field Measurements in Geomechanics

Andrew Ridley

The 2015 Symposium on Field Measurements in Geomechanics (FMGM) was held at the Sheraton on the Park hotel in Sydney, Australia from 9th to 11th September 2015. Over 200 delegates from thirty-two countries attended the symposium and 33 companies showcased their products at the impressive exhibition. The Symposium was preceded by two workshops, one on InSAR and Emerging Technologies and the other on Radar and Monitoring. These were attended by over forty delegates. The Symposium and the Workshops were organised by the Australian Centre for Geomechanics and sponsored by IDS, Geokon and PSM. The organising committee, Chaired by Professor Phil Dight and Mark Fowler should be congratulated on a magnificent achievement.

In his opening address to the Symposium Mark Fowler pointed out that “it is hard to escape the reality that technology in everyday life is advancing so rapidly, and it is not just changing our lives, but in fact shaping it. The pervasiveness of smart phones and tablets, cloud computing, drones—data vacuums of the air—and the potential benefit and threat of big data may individually and/or collectively enrich and exploit our lives. Geotechnical monitoring is no exception. It’s hard not to think we are in or approaching the golden age of monitoring and there is no question that these advances have, and will,

Friends gather for the traditional symposium dinner. At right front, Elmo DiBiagio, the only person to have attended all nine FMGMs greatly further our profession." Inspiring words indeed!

During the three day Symposium programme sixty five papers were presented. The scene was set with an excellent presentation from Dr Philip Pells entitled "Monitoring – the good, the bad and the ugly" highlighting the pitfalls when the application of instrumentation is poorly understood. The presentation, which focused on some well-known case histories such as the double helix underground car park at Sydney Opera House (the "Good"), the Heathrow Express tunnels (the "Ugly") and Vaiont Dam (the "Very Ugly") reminded us that monitoring, whether simple of complex, should only be implemented if we have valid theoretical and physical models against which to evaluate the results. Pells also told us that it is very important to listen to those who disagree with us, particularly experienced geologists because they often see things that engineers miss. Wise words indeed and a reminder that our subject is not just about the gadgets and the data. Keynote addresses were also given by Dr Andrew Ridley (UK) on "Soil suction – what it is and how to measure it"; Martin Beth (France) on "The challenges of supplying good quality and useful data for significant projects"; Dr W Allen Marr (USA) on "Performance monitoring as a risk management tool in dam safety" and Dr Ian Gray (Australia) on "The measurement and interpretation process to determine the state of stress in rock including the effects of fluid pressure."

The conference was divided into morning plenary sessions and afternoon parallel sessions. The subjects covered were emerging technologies, tunnelling, water flow, mining, transport infrastructure, slope stability and case histories. The Best Young Engineer Paper Award was given to Michele Salvoni for his paper entitled "Improvement of pseudo-3D pit displacement mapping technique through geodetic prism data integration." In addition to the prestige and the monetary prize Michele was also invited to represent young professionals on the new FMGM Secretariat, a development that was introduced to the delegates during the Symposium.

The traditional symposium dinner was held on a Sydney Harbour boat cruise which showcased, to the 130+ international and local attendees and their guests, the fantastic harbour and its iconic landmarks.

As had been agreed in Berlin (2011) the next FMGM Symposium will be held in Rio de Janeiro, Brazil in 2018. The local organising committee, led by Professor Pedricto Roche Filho (PUC-Rio) will be supported by a new permanent FMGM Secretariat. The Sydney Symposium was informed of the new Secretariat (a new development) by Andrew Ridley. The Secretariat will be hosted by the British Geotechnical Association and is composed of representatives from the existing International Advisory Panel and new people from across the international community. Further information to come.

In summary I would say that the 2015 FMGM Symposium was another overwhelmingly successful event and the long trip (for many of us) was very much worthwhile. I look forward to the next Symposium in Brazil and renewing enduring friendships.

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The Future of FMGM

Andrew Ridley

FMGM is an acronym derived from the name of a series of international symposia entitled "Field Measurements in Geomechanics" that deal with the use of instrumentation to monitor the performance of engineering structures. The applications include dams, foundations, tunnels and other underground openings, embankments, natural slopes, land reclamation, mining facilities, repositories for industrial or nuclear waste and offshore structures. The FMGM symposia are staged every three or four years; the last symposium was held in Sydney Australia in September 2015 and the next will be held in Rio de Janeiro, Brazil in July 2018.

Until now FMGM has been run in an informal way, the responsibility for the symposia being handed over from one group to the next, essentially based on personal relations and friendships. Chairpersons of previous symposia and their professional associates have functioned as a *de-facto* Secretariat. There has not been any fixed procedures or even statutes on how to proceed with the symposia in the future or how to organise FMGM as a whole. Nevertheless all previous symposia, since the first in Zurich in 1983, have been successful and generated a lot of international interest in the specialised topics dealt with.

Despite the success of the *de-facto* arrangement there is no guarantee that FMGM will continue to be as successful in the future and therefore during the 8th International FMGM Symposium, held in Berlin in 2011, a general assembly was held to discuss the future of the symposia. It was agreed that a formal FMGM Secretariat should be established. Several people and organisations were contacted about this and the British Geotechnical Association (BGA) has agreed to host a Secretariat for FMGM. This was formally announced at the Sydney symposium. The new FMGM Secretariat will be formed as a subcommittee of the BGA Executive Committee and will be made up of people from the BGA Executive Committee, the existing FMGM supporters and other co-opted people. The new FMGM secretariat will have its own financial arrangements, sitting under the current BGA financial organisation and to date over £10,000 has been pledged by companies and organisations with interests in the subject. During the Sydney symposium several people were approached and agreed to participate in the committee affairs of the new Secretariat. In addition an FMGM LinkedIn discussion group (named "Field Measurements in Geomechanics") has been initiated to distribute information.

The principal aims of the new Secretariat are to:

1. Set up and maintain a list of persons, organisations and institutions that want to be associated with FMGM.
2. Establish and develop a new FMGM website.
3. Distribute an annual newsletter.
4. Establish financial independence for FMGM. This has and will continue to be done by approaching members of the FMGM community, particularly service providers and instrumentation suppliers, for financial support in running the Secretariat.
5. Establish written guidelines for future FMGM Symposia, including how to decide where they should be held, how to run the symposia, how to share the risks between local organisers of an FMGM symposium and the FMGM Secretariat and updating the guidelines after each symposium and;
6. Explore the feasibility of establishing an international FMGM Society or a Technical Committee on Field Measurements as part of the International Society of Soil Mechanics and Geotechnical Engineering.

Anyone wanting more information about the new FMGM Secretariat can write in the first instance to Andrew Ridley (andrew@geo-observations.com) or join the LinkedIn discussion group and post a comment.

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