

Introduction by John Dunnycliff, Editor

This is the seventy-second episode of GIN. Two articles this time.

Remote methods for monitoring deformation

In the March and June 2012 episodes of GIN there were seven one-page articles about different remote methods for monitoring deformation. I promised a “concluding article with a comparative analysis of the various techniques”. Yer tiz (here it is), as they say in this rural part of southwest England. The author, Paolo Mazzanti, was the winner of the “Forum for Young FMGM Engineers” (“young” defined as under 35) at the 2011 Eighth International Symposium on Field Measurements in GeoMechanics (FMGM) symposium in Berlin, for his paper on *Temporal prediction of landslides failure by continuous TInSAR monitoring*. He wrote on the same subject for June 2011 GIN, and again for the

one-pager in March 2012 GIN. For his contributions, in particular for his article in **this** GIN, I’m awarding him the informal “Winner of the Forum for Young GIN Engineers”. Congratulazioni Paolo!

Field monitoring for improved mine backfill systems

The article by Murray Grabinsky, Ben Thompson and Will Bawden is the first in GIN by mining engineers. Why has it taken so long? As a non-mining engineer, I found it very interesting and educational—we’ve tried to cross-pollinate by including enough text to clarify mining terms and procedures. I recommend that we **all** pay attention to the lessons learned—I very much welcome the text on training and empowering the workforce.

The next continuing education course in Florida

This is scheduled for April 7-9, 2013 at Cocoa Beach. Details are now on www.conferences.dce.ufl.edu/geotech. Also see the announcement on page 33. The deadline for the early registration discount expires on March 1, 2013.

Closure

Please send contributions to this column, or an abstract of an article for GIN, to me as an e-mail attachment in MSWord, to

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Za vashe zdorovye! (Russia)

Remote monitoring of deformation. An overview of the seven methods described in previous GINs

Paolo Mazzanti

Introduction

During the past 10 years there have been rapid developments of remote sensing methods for monitoring deformation, creating significant

applications in the geotechnical field. Following the seven one-page articles that were published in March and June 2012 GIN, this article provides a general overview of the methods. I’m conscious that a comprehensive cover-

age of this large and complex subject would require an entire book instead of a short article, hence please accept that significant simplifications have been introduced.

Contact versus non-contact (remote) monitoring

Traditional geotechnical monitoring is based on a “contact” approach. In other words, the sensors are installed directly in contact with the ground/structure, both on the surface (e.g. crackmeters) or inside (e.g. inclinometers). In contrast, most remote methods are based on a “non-contact” approach, i.e. the data collection is based on sensors that are installed far away from the monitoring site. However, based on the degree of interaction with the ground/structure, remote monitoring methods can be divided in two main subcategories:

- **Partially remote.** Defined as those methods that, even if based on a remote sensor, require the installation of some additional sensors or targets at the monitoring site (e.g. antennas for D-GPS, prisms for total stations).
- **Fully remote.** Defined as those methods that do not require any installation at the monitoring site.

When moving from contact monitoring to fully remote monitoring, the following changes must be considered:

- A progressive reduction of interaction with the ground/structure.
- An increasing size of the investigated area.
- A progressive reduction of the localization precision of the monitoring point (spatial resolution).
- An increasing of the spatial information density.

Furthermore, for remote methods, noise related to wave propagation through the atmosphere must be accounted for. Hence, when moving from contact to non-contact monitoring an increased complexity in data processing and care in the data analysis and interpretation is required.

Remote methods: a quick overview

A brief description of the basic operating principle of the seven methods is presented below, together with a clas-

sification based on the following main features:

- Type of platform. The type of platform will be divided on the basis of the sensor location:
 - “ground based” when the sensor is installed on the ground surface;
 - “aerial based” when the sensor is installed on an airplane;
 - “satellite based” when the sensor is installed on a satellite.
- Type of wave. The type of wave that the sensor collects will be divided on the basis of the following categories:
 - visible (wavelength range: 400nm – 700nm);
 - infrared (wavelength range: 700nm – 1mm);
 - microwaves (wavelength range: 1mm – 1m);
- Type of sensor. Sensors will be divided between active and passive:
 - “active sensors”, emit a wave and receive the reflection of the emitted wave from the ground/structure;
 - “passive sensors” receive the wave naturally emitted by the ground/structure following a “natural” emission (e.g. the sun).

Terrestrial laser scanning (TLS)

TLS is a ground based fully remote technique that uses a visible and near infrared wave active sensor. TLS collects the coordinates of several points, thus achieving 3D models of the ground/structure. By comparison of point clouds collected at different times, ground/structure deformation is detected. The main fields of application are slope instabilities, dams and mines.

Terrestrial interferometric synthetic aperture radar (TInSAR)

TInSAR is a ground based fully remote technique that uses a microwave active sensor. TInSAR collects 2D images of large areas (few km²) with a high sampling rate. By comparison of SAR images collected at different times, ground/structure deformation is detected. The main fields of application are slope instabilities, dams, mines, heritage structures and civil buildings.

Robotic total station (RTS)

RTS is a ground based partially remote technique that uses a visible or near infrared active sensor. RTS collects the precise position of several prisms installed on the ground/structure. By comparison of the prism positions at different times, ground/structure deformation is detected. The main fields of application are slope instabilities, dams, mines, civil buildings and heritages structures.

Reflectorless robotic total station (RRTS)

RRTS is a ground based fully remote technique that uses a visible or near infrared active sensor. RRTS collects the precise position of several natural targets on the ground/structure. By comparison of the natural target position at different times, ground/structure deformation is detected. The main fields of application are tunneling in urban areas, civil buildings and heritages structures.

Satellite interferometric synthetic aperture radar (SInSAR)

SInSAR is a satellite based fully remote technique that uses a microwave active sensor. It is based on the collection (since 1992) of 2D images of large areas (several km²) with a low sampling rate. By comparison of images collected at different times, ground/structure deformation is detected. The main fields of application are fluid extraction/pumping, tunneling in urban areas, civil buildings and slope instabilities.

Digital photogrammetry (DP)

DP is a ground, aerial or satellite based fully remote technique that uses a visible passive sensor. DP collects 2D optical images from different positions of the ground/structure, thus achieving 3D ground models. By comparison of the 3D models at different times, ground/structure deformation is detected. The main field of application is slope instabilities.

Differential global positioning system (D-GPS)

D-GPS is a satellite based partially remote technique that uses a microwave active sensor. D-GPS collects the precise position of GPS sensors installed on the ground/structure. By comparison of the GPS sensor positions at different times, ground/structure deformation is detected. The main fields of application are fluid extraction/pumping, tunneling in urban areas, slope instabilities, dams and civil buildings.

How to evaluate a remote sensing method

In evaluating a remote sensing method for monitoring purposes several parameters and features must be considered. In what follows a brief description of the main relevant features is presented:

- **Precision:** maximum repeatability of measurements.
- **Temporal resolution:** maximum frequency in data collection.
- **Spatial resolution:** maximum resolution of pixels at the ground/structure, i.e. minimum size of the area where deformation value is provided.
- **Information density:** the density of information in terms of number of pixels and their areal distribution.
- **Deformation geometry:** geometrical information of the deformation measurement (e.g. unidirectional predefined, unidirectional, bidirectional, 3D, etc).

- **Degree of interaction with the ground/structure:** interaction with the monitored area (from zero for the fully remote techniques, to high for techniques that required the installation of sensors on the ground/structure).
- **Size of the monitored area:** maximum size of the area that can be monitored simultaneously by a single sensor.
- **Data reliability and validity:** reliability of achieved results.
- **Maximum operability range:** maximum distance to which the deformation of a target (artificial or natural) can be determined.
- **Atmospheric noise:** degree of sensitivity to the atmospheric noise.
- **Budget:** cost required for the monitoring.

For each of the above mentioned features there is a very wide range of variability among the techniques discussed in this article (Figure 1). Figure 2 presents a qualitative rating of the above features. However, it must not

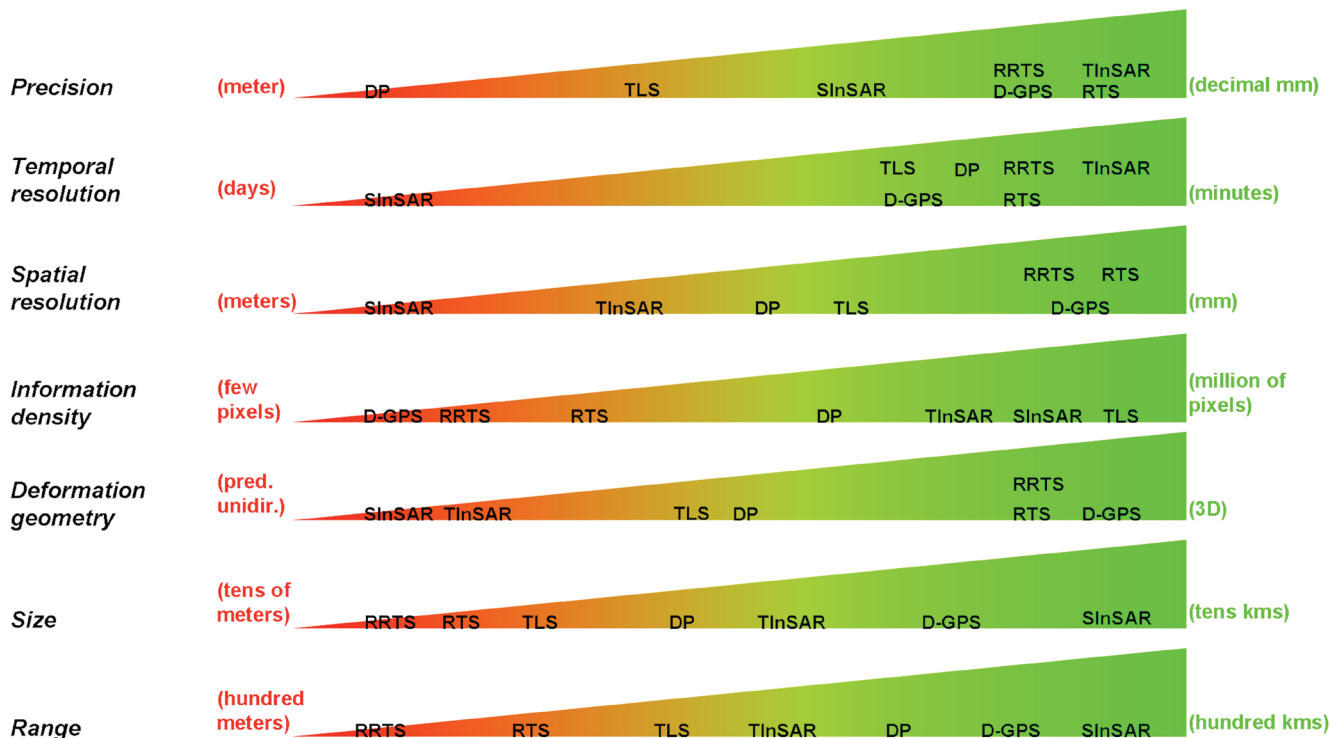


Figure 1. Range of variability of some features described in the text with respect to each method. The values in the parentheses identify the “end members” (in red the worst values, in green the best values).

	Precision	Temporal resolution	Spatial resolution	Density	Deformation geometry	Interaction	Size monitored area	Operability range	Data reliability	Atmospheric noise	Costs
<i>TLS</i>	High	High	High	High	High	High	High	High	High	Ext. Low	Ext. High
<i>TInSAR</i>	High	High	High	High	Ext. Low	High	High	High	High	Ext. Low	Ext. High
<i>RTS</i>	High	High	High	High	High	High	High	High	High	Ext. Low	Ext. High
<i>RRTS</i>	High	High	High	High	High	High	Ext. Low	Ext. High	High	Ext. Low	Ext. High
<i>SInSAR</i>	High	Ext. Low	Ext. Low	High	Ext. Low	High	High	High	High	Ext. Low	Ext. High
<i>DP</i>	Ext. Low	High	High	High	High	High	High	High	Ext. Low	Ext. Low	High
<i>D-GPS</i>	High	High	Ext. Low	Ext. Low	High	Ext. Low	High	High	High	High	High

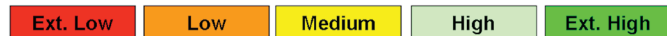


Figure 2. Qualitative evaluation of remote techniques based on the features describe in this article. From red color to green color (see at the scale bar) there is an increasing performance of the technique (e.g. increasing precision, temporal resolution, spatial resolution, density, geometric information, monitoring area, operability range, data reliability) and decreasing (e.g. atmospheric noise, cost, and interaction).

be forgotten that some of the features are strongly influenced by the type of monitoring, the specific site conditions, the monitoring purpose etc.

The right solution for the right application

I'd like begin this section by quoting some classic words of wisdom by Ralph B. Peck, since they are the

essence of observational method and monitoring:

- An instrument too often overlooked in our technical world is a human eye connected to the brain of an intelligent human being.
- The observational method, surely one of the most powerful weapons in our arsenal, is becoming discredited by misuse. Too often it is invoked by name but not by deed.

- There is a danger that instrumentation may be discredited because of indiscriminate use.
- We need to carry out a vast amount of observational work, but what we do should be done for a purpose and done well.

These four quotations are highly relevant when a person considers using of any of the methods described in this article. The rapid development

	ADVANTAGES	LIMITATIONS
<i>TLS</i>	<ul style="list-style-type: none"> ▪ High density of information ▪ Good view of results thanks to the 3D models ▪ Long distance measurement 	<ul style="list-style-type: none"> ▪ Low accuracy ▪ Difficult data management ▪ Not effective in rainy and cloudy weather
<i>TInSAR</i>	<ul style="list-style-type: none"> ▪ High density of information ▪ High accuracy and precision ▪ Effective in any weather conditions 	<ul style="list-style-type: none"> ▪ Difficult data processing ▪ Unidirectional measurement of deformation ▪ Phase ambiguity
<i>RTS</i>	<ul style="list-style-type: none"> ▪ High accuracy and precision ▪ 3D monitoring ▪ Easy to use 	<ul style="list-style-type: none"> ▪ Interaction with ground/structure (target required) ▪ Not effective in some lighting and weather conditions (fog, rain etc) ▪ Low accuracy at large distances
<i>RRTS</i>	<ul style="list-style-type: none"> ▪ Cost effective ▪ 3D monitoring ▪ Easy to use 	<ul style="list-style-type: none"> ▪ Limited range and incidence angle ▪ Not effective in some lighting and weather conditions (fog, strong sun, rain etc) ▪ Limited number of investigated points
<i>SInSAR</i>	<ul style="list-style-type: none"> ▪ Monitoring at regional scale (large areas) ▪ Analysis of historical deformation (since 1992) ▪ High information density 	<ul style="list-style-type: none"> ▪ Low temporal frequency ▪ Unidirectional measure of deformation ▪ Low spatial resolution
<i>DP</i>	<ul style="list-style-type: none"> ▪ Simultaneous monitoring of large areas ▪ Cost effective ▪ Analysis of historical deformation 	<ul style="list-style-type: none"> ▪ Not effective in some lighting and weather conditions (fog, strong sun, rain etc) ▪ Low accuracy and precision ▪ Low temporal frequency
<i>D-GPS</i>	<ul style="list-style-type: none"> ▪ Monitoring of deformation along the three main directions ▪ Effective in any weather conditions ▪ Easy to use 	<ul style="list-style-type: none"> ▪ Strong interaction with the ground/structure ▪ Low precision in the short term analysis ▪ Low information density

Figure 3. Main advantages and limitations of the methods for remote monitoring of deformations.

	Slope instabilities	Tunnelling in urban area	Fluid extraction/pumping	Quarry and mines	Dams	Heritages	Civil buildings
TLS	High	Ext. Low	Ext. Low	Medium	High	Ext. Low	Ext. Low
TInSAR	High	Ext. Low	Medium	High	High	High	Medium
RTS	High	High	Medium	Medium	High	High	High
RRTS	Medium	High	Ext. Low	Ext. Low	High	Medium	High
SInSAR	Medium	Medium	High	Medium	High	Ext. Low	Ext. Low
DP	Medium	Ext. Low	Ext. Low	Medium	Ext. Low	Ext. Low	Ext. Low
D-GPS	Medium	High	High	Medium	High	Medium	High

Ext. Low
Low
Medium
High
Ext. High

Figure 4. Qualitative evaluation of the performance offered by all the remote methods for different geotechnical applications. From red color to green color (see at the scale bar) there is an increasing performance of the method.

of these somewhat complex methods runs the risk of a person being carried away by the excitement of innovation while ignoring the above words of wisdom.

In what follows I will try to give some suggestions applicable to “doing well” with these seven methods for remote monitoring of deformation.

First, the main advantages and limitations of each method are summarized in Figure 3, thus identifying the main opportunities offered by the methods, but also providing an understanding of constraints. For example, if you are looking for a short time 3D monitoring of deformation at a specific location with high data sampling frequency, it can be seen that SInSAR is not suitable, while RTS is more appropriate. If you are interested in monitoring past deformations of a large area with high accuracy, you can see that SInSAR is probably the only available method.

Focusing on the geotechnical applications is more difficult, since the number of cases to be considered is very wide, and each one is likely to be

characterized by specific site conditions that require a unique evaluation. However, the following general applications are identified below and in Figure 4.

- **Slope instabilities:** monitoring of unstable slopes for both investigating purposes and continuous control.
- **Tunneling in urban areas:** monitoring of local deformation induced by underground excavation.
- **Fluid extraction and pumping:** monitoring of topographic changes related to fluid or gas extraction variation both at local and regional scale.
- **Quarries and mines:** real time monitoring of slope instabilities during mines exploitation.
- **Dams:** monitoring of dams deformation for testing and control purposes.
- **Heritage structures:** monitoring of high value cultural heritage for safety purposes.
- **Civil buildings:** monitoring of standard buildings for safety purposes.

To emphasize with rating provided in Figure 4 is appropriate only for ‘standard’ applications. The suggestions are not applicable for ‘non-standard’ applications, where only a specific and advanced design can provide the best solution. For example, for the periodic monitoring of fast-moving landslides, DP or TLS can be more appropriate than TInSAR and other methods, while for the real-time monitoring of localized subsidence related to fluid extraction, TInSAR can be more appropriate than SInSAR (thus contradicting Figure 4).

Conclusions

Methods for remote monitoring of deformation are gaining popularity within the geotechnical community because they offer several new opportunities. Sometimes they can be alternatives to traditional contact methods, but more frequently they can be integrated with them. They are also opening new opportunities in the geotechnical field, such as monitoring for “investigative purposes. Features

such as high information density, monitoring historical deformation, simultaneously viewing large areas without interaction with the ground/structure are very important if you use deformation as a tool for “understanding” geotechnical or geological processes. In this way, monitoring of deformation can be a useful additional tool for use during the preliminary design phases of projects.

However, adoption of these fascinating opportunities can lead to expensive equipment, complex data processing, difficult interpretation of results, and some limitations that may lead to misleading conclusions. To repeat, *we need to carry out a vast amount of observational work [also using remote methods], but what we do should be done for a purpose and done well.*

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Field monitoring for improved mine backfill systems

M.W. Grabinsky, B.D. Thompson, W.F. Bawden

Introduction

The large voids created by underground mining are backfilled to provide regional ground support. Our understanding of backfill behaviour has improved significantly using elaborate field monitoring techniques¹; however this article will instead focus on simplified systems for routine monitoring. A brief explanation of the engineering problem is first provided

for those readers unfamiliar with mining processes and terminology.

Brief overview of underground mining procedures and terms

The mineralized zone to be exploited is called a stope (Figure 1). Undercut and overcut access tunnels are created so that the ore in the stope can be drilled and blasted, with the blasted ore being extracted through the undercut. A steel reinforced shotcrete barricade is then constructed within the undercut and slurry backfill is delivered through the overcut. The backfill typically contains silt to sand size granular material at up to 70% solids content, and also contains Portland cement binder. Some of the water in the slurry must drain, and the binder must cure (hydrate) so that the backfill gains the stiffness and strength required to support the surrounding rock mass during subsequent mining of adjacent stopes.

ing on the barricade, and (ii) to assess if the backfill is properly curing. These concerns are addressed by monitoring total pressure, pore water pressure, and temperature. It is also necessary to estimate backfill height within the stope as a function of time. This is done by conducting a cavity monitoring survey (CMS) to determine stope geometry prior to filling, and then using the volume-rate of backfill delivery to calculate the average backfill elevation as a function of filling time. Instrument locations within the void must also be determined using standard survey techniques.

Expected results

Backfills deposited as slurries will initially generate an isotropic total pressure equal to the unit weight of the backfill x depth below the deposition surface. In this case both piezometers and total earth pressure cells (TEPCs) will register the same total pressures. The primary mechanisms believed to be responsible for pore water pressure dissipation are drainage and water consumption during binder hydration (i.e. chemical shrinkage or self-desiccation). When either mechanism occurs the measured pore water pressure will become lower than the total

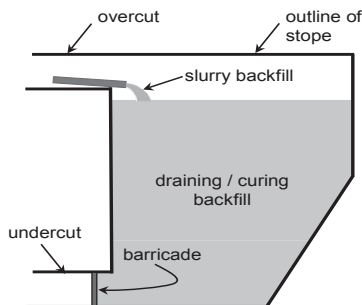


Figure 1. Vertical cross section through a mined area of the mineralized zone.

Purpose and approach of the monitoring program

Design concerns and what needs to be monitored

The immediate mine design concerns are (i) to determine the pressures act-

¹ see cover photos on the September 2009 and June 2012 issues of Geotechnical News, and the free technical article at <http://www.nrcresearchpress.com/doi/abs/10.1139/t2012-040>

pressure, indicating the onset of effective stress and therefore enhanced backfill stiffness and strength. In addition, exothermic binder reactions are reflected in rising temperatures. It is therefore desirable to see effective stress and temperature rise occurring simultaneously. An example of such a data trend is shown in Figure 2. Note that Figure 2 also includes vertical total stress as a matter of interest, although this would not generally be required for barricade monitoring.

Suggested instrumentation strategy

Transducer types

Although measuring pore water pressure is relatively straightforward, there are many well documented issues associated with measuring total pressures in a granular material. One significant issue is matching the stiffness of the TEPC with that of the surrounding medium. This is all the more difficult when the stiffness of the material is changing, as is the case for backfill.

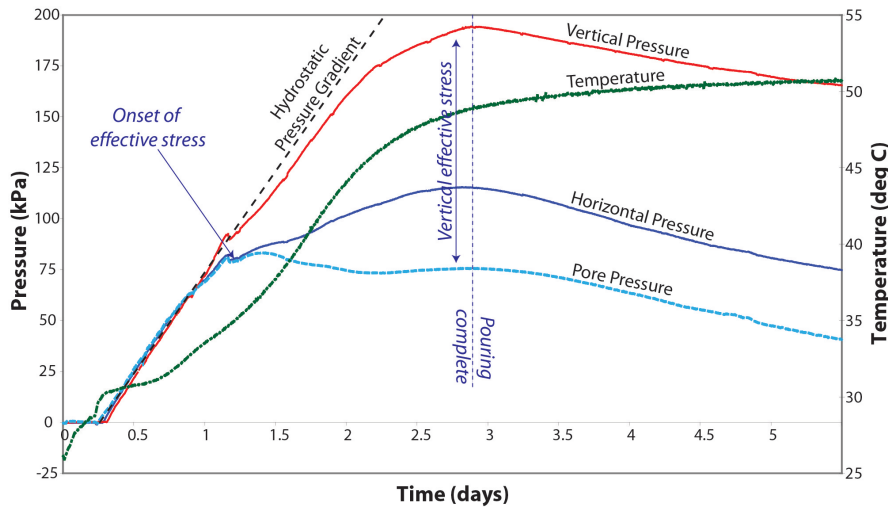


Figure 2. Ideal monitoring data showing temperature increase and development of effective stress (i.e., total pressure exceeding pore water pressure).

Interpretation of results

The monitored parameters are interpreted both quantitatively and qualitatively. The total pressure acting on the barricade must remain below its rated safe limit, otherwise backfilling must be stopped so that pressures can subside before backfilling resumes. Ideally, the onset of effective stress and temperature rise should be observed before the backfill reaches the full barricade height, as this condition indicates that the barricade is now beginning to interact with solid to semi-solid material.

The approach taken in this work was to use TEPCs with the highest practical aspect ratio (diameter:thickness) and stiffness possible. The merits of this approach can be debated but such details, while important, are beyond the scope of the current article.

TEPCs and piezometers of the vibrating wire type have been used, supplied by two leading manufacturers. The TEPCs used have been about 250 mm (10 in.) diameter with sensing surface on one side (also called “contact cells”) and about a 20:1 aspect ratio. All of the transducers have thermistors and provide a temperature data channel. During the initial filling stage, while the backfill is still a fluid, both manufacturers’ TEPCs have given

pressure readings consistent with the piezometer up to the onset of effective stress, which is one of the critical indicators of good backfilling practice. Subsequently, there appear to be TEPC response differences that cannot be currently adequately explained, and therefore further research is needed into the performance of these cells in curing backfill where the stiffness changes with time.

Transducer calibration

Manufacturers provide calibration sheets for their vibrating wire piezometers and TEPCs. The thermal and fluid pressure calibrations have been found consistently reliable for many hundreds of transducers used in the field to date. However, as explained above, TEPC calibration is much more problematic when the stiffness of the material changes with time, and it is therefore not advised that mine-specific TEPC calibration be attempted at present. Indeed, there are other logistical considerations that can be far more influential on the output of TEPCs, and so attention to detail in the construction and deployment of the system is a more important consideration.

Building and deploying a system

At least one TEPC and one piezometer are recommended for routine barricade monitoring. These transducers should be installed at the same elevation so that piezometer readings can be directly subtracted from TEPC readings to obtain effective stress. Mounting the transducers directly to the back of the structural barricade is not recommended, as variations in barricade stiffness and drainage conditions make measurements there too localized. Instead, it is recommended that the transducers be placed within the backfill about 2 m behind the barricade and at about one-third barricade height. Ideally the mine should work with the instrumentation supplier to have an instrumentation module pre-built so that the two transducers are delivered on a frame that can be easily

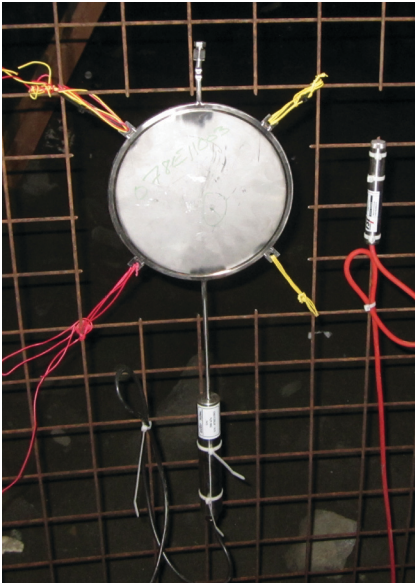


Figure 3. A pre-built instrumentation module with single connection to the data acquisition system.

and quickly erected and anchored (Figure 3). The transducers should be pre-wired with a single connector that attaches to a portable data acquisition system. The data acquisition system should then be configured to the mine's data backbone so that the information is fed to the backfill plant on the surface. Plant operators must be trained to interpret these results and

decide if and when a plant shutdown is required.

Visual monitoring

In addition to the pressure and temperature monitoring, it is valuable to provide a camera feed to the backfill plant so that the operators can also visually monitor the overall barricade response to backfilling (Figure 4). There have been instances where a small construction defect has led to localized barricade failure and release of backfill, and such localized response would probably not be picked up by the instrumentation system. Had the barricade been monitored visually the operators would have seen cracks developing and leakage from these cracks, and a plant shutdown to investigate and possibly remediate the barricade could have prevented its ultimate failure.

Lessons learned

In addition to the recommendations already mentioned, the following should be considered by mines embarking on routine backfill monitoring programs.

Have a supplier build a system

The essential components of the system have already been mentioned:

instrumentation module; dedicated data acquisition system; data networking to surface; camera feed. Ideally the mine should work with a supplier who can build a suitable system to the mine's specification and then support that system in the field. It has been extremely valuable to have the supplier's technician on site for the first instrumentation installation and monitoring, to train mine personnel in verifying system performance and trouble-shooting any problems prior to backfilling.

Transducer range, resolution, and accuracy

Barricades typically have a safe pressure rating in the range of 100 – 200 kPa, although the trend is towards better barricades with increased safe pressure ratings. One of the manufacturers supplies a 1 MPa vibrating wire TEPC with a quoted resolution of 0.25 kPa minimum which is certainly sufficient for barricade monitoring. One must be careful when interpreting a manufacturer's claims of TEPC accuracy, however, as such figures do not reflect the performance of the entire TEPC installed in the field, where the accuracy of the transducers output can be influenced by factors such as stiffness of the surrounding medium.

Protect the data cables

Once the instrumentation has been installed, the connecting data cables need to be covered with a protective sand berm. The sand berm can extend through the base of the structural barricade and will actually act as a drain/filter which is marginally beneficial to barricade performance.

Zero the instruments

A TEPC that is built and calibrated (zeroed) near sea level will register an initial positive pressure underground, reflecting the increased air pressure arising from the mine's ventilation system. This initial reading needs to be zeroed out for engineering calculations that are based on gauge pressures (i.e. relative to the ambient pressure). Also, the piezometer tip needs to be



Figure 4. Backfill plant operator monitoring barricade pressures and video feed in real time, in order to optimize slope filling.

saturated (following the manufacturer's recommendations) and the initial reading zeroed.

There has also been an instance where a problem with a data acquisition unit occurred during filling, and a second unit was connected to the transducers while the fill proceeded. In this case the second unit needs to be calibrated to start pressure readings where the previous unit left off (i.e. if this second unit is zeroed then the accumulated pressures to that point will not be accounted for).

Train and empower the workforce

The best results have been obtained when all involved mine personnel are made fully aware of why the instrumentation is being installed and how it is supposed to operate. Underground construction crews have developed novel, site-specific ways of best deploying the instruments. Backfill plant operators and underground inspection personnel have been trained

in the expected system performance and also in the signs that might suggest undesired backfilling behaviour, and a protocol has been established for reporting early warning signs and invoking an emergency shutdown.

Develop a site-specific database

It is critical that the mines keep records of each fill and correlate the filling performance with relevant operating parameters such as backfill material properties (mineralogy, water chemistry and content, and binder type and content), ambient temperature and humidity, and backfill rise rates. Regular comprehensive engineering reviews of these experiences will then allow fine-tuning of the backfilling operation to optimize the costs and benefits.

Summary

Attention to detail in the design, construction, deployment and monitoring of underground mine backfill sys-

tems can result in robust and reliable monitoring programs that provide both qualitative and quantitative information. Careful engineering interpretation of monitoring results over a wide range of backfilling conditions can then help the engineering team to optimize the mine's backfill operations.

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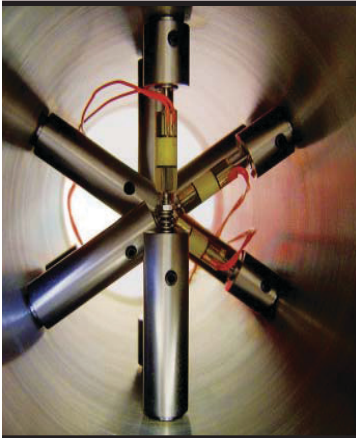
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- Brief abstract of thesis (not more than 300 words)
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The University of Florida
**Geotechnical Instrumentation (GI)
for Field Measurements**

April 7-9, 2013

Doubletree Hotel • Cocoa Beach, Florida

Course Director: John Dunnycliff, Consulting Engineer

COURSE EMPHASIS: is on why and how to use GI to monitor field performance. The course will include planning monitoring programs, hardware and software, recent developments such as web-based and wireless monitoring, remote methods for monitoring deformation, case histories, and lessons learned. Online sources will be included, together with an open forum for questions and discussion.

AUDIENCE: engineers, geologists and technicians who are involved with performance monitoring of geotechnical features of civil engineering projects and project managers and other decision-makers who are concerned with management of RISK during construction.

OBJECTIVE: to learn the who, why, and how of successful geotechnical monitoring while networking and sharing best practices with others in the GI community.

INSTRUCTION: provided by leaders of the GI community, representing both users and manufacturers:

Marcelo Chuaqui, Monir Precision Monitoring

Loic Galisson, SolData Group

Pierre Gouvin, GEO-Instruments

Aaron Grosser, Barr Engineering

Daniele Inaudi, Roctest/Smartec

Allen Marr, Geocomp

Paolo Mazzanti, NHAZCA

Justin Nettle, Federal Energy Regulatory Commission

Tony Simmonds, Geokon

Rodolfo Saavedra, DG-Slope Indicator

Robert Taylor, RST Instruments

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