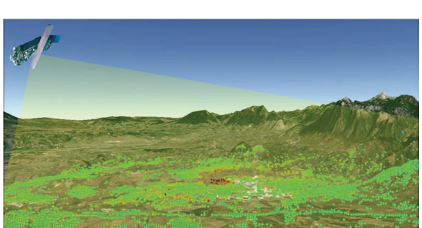
Introduction by John Dunnicliff, Editor

This is the 89th episode of GIN. Just one article this time.

Remote monitoring of deformation

During the 2011 Symposium on Field Measurements in Geomechanics (FMGM) in Berlin there were a large number of papers describing remote methods of monitoring deformation. I was so confused by the many acronyms that I invited various colleagues to contribute explanatory articles for GIN. This resulted in seven articles in March and June 2012 GIN (remember that you can read these by clicking on the appropriate month on www.geotechnicalnews.com/instrumentation_news.php):

- Terrestrial laser scanning (TLS), by Matthew Lato, March.
- Terrestrial interferometric synthetic aperture radar (TInSAR), by Paolo Mazzanti, March.
- Robotic total station (RTS), by Rob Nyren, Ryan Drefus and Sean Johnson, March.
- Reflectorless robotic total station (RRTS), by Damien Tamagnan and Martin Beth, March.
- Satellite interferometric synthetic aperture radar (SInSAR), by Francesca Bozzano and Alfredo Rocca, June.
- Digital photogrammetry (DP), by Raul Fuentes and Stuart Robson, June.
- Differential global positioning system (D-GPS), by Jason Bond and Rob Nyren, June.



Differential Satellite SAR Interferometry. Graphic by Alfredo Rocca, HHAZCA.

In December 2012 GIN, Paolo Mazzanti contributed an overview of those seven methods. His article included comparative evaluations of the seven methods, a table of advantages and limitations, and a table indicating applicability of each method for various project-type applications. In my view this octet formed one of the most reader-friendly groups of articles in the history of GIN.

Here's a ninth, with yet another acronym – manual reflectorless total station monitoring (MRTS), by Colin Hope and Stephen Dawe of Monir Precision Monitoring. This article shows that, under typical site conditions, accuracies can range from +/-4mm to +/- 2mm.

Please be aware that my colleagues who organize the annual monitoring courses in Italy (see below) have great expertise in the various remote methods for monitoring deformation, and many will be covered during the June course in Rome.

Fourth International Course on Geotechnical and Structural Monitoring, June 13-15, 2017 in Rome, Italy.

The course schedule is now on www.geotechnicalmonitoring.com. Registration for the course can be made on **www.geotechnicalmonitoring.com/en/registration.**

Registration for the June 12 Master Classes can be made on the same site. Master Classes and leaders will be:

1. Piezometers: Tony Simmonds, Geokon Inc., USA
2. Inclinometers: Erik Mikkelsen, GeoMetron Inc., USA
3. Extensometers: Giorgio Pezzetti, SMAK s.a.s., Italy
4. Total stations: Martin Beth, SIXENSE Soldata, France
5. Global navigation satellite system (GNSS): Stefano Gandolfi; University of Bologna, Italy
6. Terrestrial Radar: Paolo Mazzanti, NHAZCA, Italy

Each class will cover the following main topics: installation, data acquisition, data processing, tricks and tips from everyday experience.

During the main course we will again have sessions on "New Monitoring Trends" and "Case Histories and Lessons Learned", with presentations given by practitioners and exhibitors.

Come and join us in magnificent Rome - a city of huge historical and cultural interest!

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**

L'chaim ('To life') – Hebrew

Manual reflectorless total station monitoring (MRTS)

Colin Hope and Stephen Dawe

Introduction

MRTS is most commonly used to monitor deflections of shoring and structures where it is not possible to install targets, most commonly due to safety or access issues. It provides a safer, easier and more cost effective way to manage the risk associated with working close to sensitive buildings, structures and infrastructure. Under typical field conditions, if work is carried out methodically with a high standard of care, accuracies can range from +/-4mm to +/- 2mm depending on atmospherics, line of sight clearance and the background surface that the measurements points are on. The background surface will impact the reflectivity of the Electronic Distance Measurement (EDM) technology used. Measurements have less background scatter when they are taken to flat surfaces while rough surfaces will cause more scattering.

History

Some of the more recent advances in distance measurement technologies occurred in the twentieth century with the introduction of radar in the 1940s, and then in the 1960s with advances in laser technology we saw the emergence of Electronic Distance Measurement (EDM) technologies. Until recently, the only means of measuring a distance electronically was by combining EDM technology with a retro prism. In the past 20 years, one of the most significant advancements in EDM technologies has been the introduction of MRTS.

The following is a partial list of some of the questions that need to be answered when planning to use a MRTS (this is in addition to any other steps carried out for the monitoring):

- Is it repeatable?
- Is the correct instrument for the job available?
- How far away or how close are the points to be monitored?
- What is the background surface to be monitored?
- What colour is the background surface?
- Is the background surface smooth or rough, are there holes in the surface?
- Will the same geometry be useable for the life of the project?
- What are the tolerances for the project and what sort of accuracies are needed?
- Is it doable?
- What sort of affects will the atmospheric conditions have on the readings?
- Has this type of structure been monitored before?
- Are there objects that lend themselves to becoming monitoring points?
- Do you have traditional controls or reflectorless controls?

In this article we discuss MRTS in regards to when it should be used and when it shouldn't be used. Some of the important considerations include:

- Instrument selection
- Background noise and scatter
- Selecting and initializing the monitoring points
- Accuracy and precision
- Measurement on two faces
- Perpendicularity
- A precise versus a MRTS experiment

Instrument selection

It is important to understand that most MRTS instruments are not suitable for precision monitoring. A precision MRTS instrument is generally one with published specifications of 2 mm + 2 ppm or less in the Electronic Distance Measurement (EDM) and one second or less in the angular measurement. The instrument used in the writing of this article was a Leica TS30. Ideally, instruments manufactured for precision monitoring will offer the best accuracy for the measurements, as they are purpose built for the job and come with on-board compensators and specialized MRTS measurement technology.

Background noise and scatter

By background noise we generally mean the scattering of the laser as it hits the measurement surface and bounces back towards the instrument. A stucco wall will have much poorer reflectivity than a smooth concrete surface. Also, the lighter the surface, the better the return of the laser will be. Some other forms of background noise are taking readings over distances greater than 80 meters, which tended to fall within an error bar of +/-4mm while closer readings were observed to be more accurate and fell within the +/-2mm range. High humidity, fog, precipitation of any kind, bad lighting, vibration, dust, smoke and strong winds will all impact the accuracy of the measurements. Figure 1 shows a poor surface for MRTS monitoring due to the rough texture of the background surface.

Selecting and initializing the monitoring points

To gain the most reliable repeatability, it is vitally important to select points that are readily identifiable through

Figure 1. Shows a poor surface for reflectorless monitoring.

the telescope with as small a chance of ambiguity as possible. Some examples of these are: paint marks already on structures and buildings, flat bolts, ink marks, nail heads, imperfections in color or marks on bricks and masonry. Keep in mind that the points may have to be read during rainy periods so they should also be visible when wet.

When the initial readings are taken, it is important to keep in mind that the geometry used for the initial readings has to be repeatable going forward. Large changes in the geometry can introduce significant ambiguity into the readings, causing them to become suspect. Bad data are worse than no data. Taking the initial and subsequent readings from a safe, stable and secure location is strongly advised. With a little bit of planning and forethought, it is possible to take accurate and precise readings from a pre-planned location(s).

Accuracy and precision

Accuracy is the truthfulness of the targets location while precision is the repeatability of measurements to the same point each time it is measured.

One of the best ways to guarantee precise results is to use the same geometry, instrument and operator for all of the readings. While this is not always possible in reality, using the same geometry as much as possible is one of the most important steps to follow. While MRTS instruments can measure to inaccessible locations, it can be hard to know what happens to the laser as it travels to and from the monitoring point or even if it is hitting the right point. Measuring to the wrong type of surface, not understanding the properties of the laser and how it is affected by atmospheric conditions and the impact of those conditions on the measurements all have varying effects. It is also important to understand what the instrument is capable of and under what conditions it operates at its best.

Measurement on two faces

Using the instrument in both faces will control any calibration errors in the instrument and is needed for the accuracy it provides for MRTS readings. By taking readings on both faces of the instrument multiple times then averaging the initial measurements of the controls and the monitoring points the measurements can be kept within a tolerable range as long as the correct procedures are followed. If large differences are noted between readings on either face of the instrument then a change in geometry to a more perpendicular location is recommended.

Perpendicularity

By keeping measurement angles within an 80 degree range as much as possible, the laser will return an accurate and precise measurement of the location of the point. A way to think of this is to stay as perpendicular to as many monitoring points as is possible. Any monitoring or control point should be within 40 degrees of the perpendicular for the most consistent and accurate readings. Figure 2 shows a graphical representation of perpendicularity.

Precise mode versus reflectorless mode experiment

The same geometry is used for each set of readings along with the same

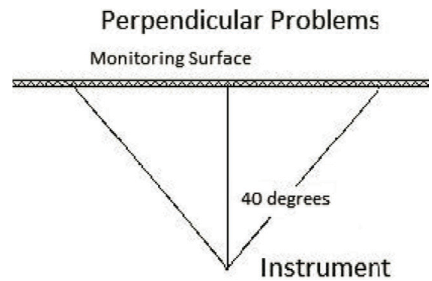


Figure 2. Shows a graphical representation of perpendicularity.

operator and instrument. All of the points being monitored were re-initialised in both precise and MRTS mode with the MRTS points also being read on two faces. Precise Mode is the method used when reflective targets are available; however, the laser is subject to deflection when objects are within close proximity of its line of flight. (Approx. 50mm) Reflectorless mode uses the changes in the phase shift as one way to calculate positons while also using the time of flight method for calculations. During the monitoring, most of the readings were taken through temporary fences which can cause problems in precise mode, as noticeable deflections occur when the precise laser travels too closely to any objects along the line of sight. Figure 3 shows a colour coded graph with reds being MRTS measurements and greens being precise measurements.

Conclusions

When there is a good geometry, when readings are taken with a high standard of care and you have the right instrument, it is a good alternative to use MRTS monitoring, especially if traditional methods are difficult or impossible.

A good geometry is a system of controls installed on at least two axes with at least five targets spread as evenly as possible, while staying as perpendicular to as many points as possible and not exceeding forty degrees from the perpendicular when taking measurements.

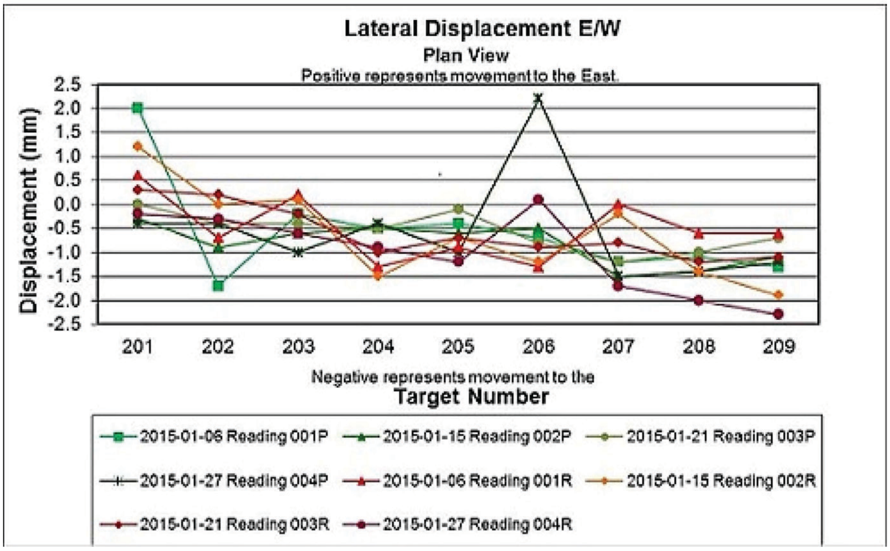


Figure 3. Shows a colour coded graph with reds being MRTS measurements and greens being precise measurements.

The right instrument is built for the job of monitoring, both in precise and MRTS measurement with compensators, a robust microprocessor for performing calculations, an easy to use interface and the right type of reflectorless laser for taking fast and accurate measurements. A sighting laser is also a very helpful tool for measuring past obstructions and helps locate objects close to or blocking line of sight.

We have determined in this experiment that through parallel using both the precise and MRTS mode monitoring, that when the conditions are right, we can achieve an accuracy of +/- 2mm, which is the same as what we achieve in precise mode. A further option is to combine the two methods when taking measurements so that background noise can be cleared out further in the field.

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IV INTERNATIONAL COURSE ON GEOTECHNICAL AND STRUCTURAL MONITORING

June 13-15, 2017 (Master Classes on June 12) - Rome (Italy)

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

2016 Participants

2016 Lecture room

Trevi's Fountain

Sapienza University's entrance

The Statue of Minerva (Sapienza University of Rome)

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:

- Many new speakers, to give the course a fresh look
- Increased sessions for professional presentations about new trends
- Increased case history sessions, 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 Rome (Italy), a city of huge historical and cultural interest

MASTER CLASSES: on the day before the main course, six Master Classes will be led by international experts, specifically oriented to provide practical basic know-how on use of the most common monitoring systems. Each class will cover the following main topics: installation, data acquisition, data processing, tricks and tips from everyday experience.

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