

Geotechnical Instrumentation News

John Dunicliff

Introduction

This is the sixty-second episode of GIN. One article this time.

Wireless Monitoring

During the last instrumentation course in Florida Allen Marr said, “Things are changing”. Yes, indeed. One of the major changes is the trend to favor wireless monitoring as opposed to a person with a portable readout unit. The following article by Ian Froggatt and his colleagues illustrates this trend, and gives justifications for wireless monitoring where slope stability is uncertain.

Delayed Article

When introducing Allen Marr’s article, “Reasons for Monitoring Performance with Geotechnical Instrumentation” in the previous episode of GIN, I promised a companion article for this episode to describe his method of quantifying benefits. Please be tolerant of a three-month delay.

Safety of Dams

A few years ago I watched and listened to six DVDs about the safety of dams. I’ve just re-watched and re-listened. Outstanding, and very educational! In my view, ‘must-haves’ for anyone involved with the design, construction or monitoring of dams.

The DVDs were produced by the Federal Interagency Committee on Dam Safety (ICODS) and are titled:

- *Seepage and Piping*, by Ralph Peck (1995)
- *Dam Foundations*, by Don U. Deere (1996)

- *Filters and Sinkholes/Rapid Draw-down Stability*, by John Lowe III (1997)
- *Ground Improvement for Dam Safety*, by James K. Mitchell (1999)
- *Behavior of Embankment Dams During Earthquakes*, by I.M. Idriss (2003)
- *Dam Breach and Flood Wave Modeling*, by Danny L. Fread (2004)

Each DVD is about two hours long. They can be ordered: www.damsafety.org/resources/?p=d1804192-9338-41f8-98ba-0362d16256bb

Next Instrumentation Course in Florida

The next course is scheduled for April 3-5, 2011 at Cocoa Beach. Details will be on <http://conferences.dce.ufl.edu/geotech> when I’ve done more planning. If you want me to let you know when the site is updated, please send me an e-mail.

Follow-up to my Plea for Articles

In the previous episode of GIN I said that I’m having an ongoing struggle to solicit articles for GIN, and pleaded for help from you. Only one positive response so far, from as far away as possible—Craig Johnson in Australia. What about the rest of you folks?

Here’s one suggestion. GIN has included several articles about new and emerging technologies, and I’m always looking for more. At a recent seminar in England Tony Simmonds, International Projects Manager for Geokon Inc. in Lebanon NH, was asked to tell us about new and emerging technologies, all in 45 minutes! He was able

to give us only a brief overview in the allotted time, and introduced the following:

- Fiber optic sensors.
- Robotic total stations.
- Global positioning system (GPS).
- Micro-electro-mechanical systems (MEMS).
- Time domain reflectometry (TDR).
- Laser scanning.
- Wireless sensor networks.
- Interferometric synthetic aperture radar (*for monitoring displacement*)
- Interferometric radar (*for monitoring displacement*)
- Modbus (*communication system*)
- Autoresonant vibrating wire sensors (*for dynamic measurements*)
- Vibrating wire noise filters
- Digital image correlation (*for monitoring displacement*)

If you have experience with any of these or other ‘new and emerging technologies’ please consider writing an article for GIN. Or if you know someone with experience, please put me in contact. I’m also looking for articles on web-based monitoring and acoustic emission (AE). The first step is a 200- to 300-word abstract—see the guidelines on www.bitech.ca/news.htm.

Retirement

Fanny Waterman founded the prestigious Leeds International Pianoforte Competition 36 years ago, and she still runs it. And when I write “runs”, I mean it! The boss of all things. Fanny Waterman is 89. In an interview this year she was asked the inevitable question about retirement,

and replied, "You don't get old and retire. You retire and get old". This reminds me of another classic: "If you enjoy your job, you never have to go to work".

To my Friends in the Manufacturing Community

I was recently given a box of Lindt truffles. Inside was a card with the following words:

Lindt's Master Chocolatiers are true masters in the art of making chocolate and they promote their craft with love and passion. They select high grade cocoa from only the best crops, such as Criollo or Trinitario, and roast them with great care.

In a machine called the "Conche", the cocoa and exquisite ingredients are combined with soft and creamy cocoa butter - resulting in a velvety texture that can at once be felt by every connoisseur.

Lindt chocolate offers an unrivalled taste sensation that satisfies all of your senses. It has an unmistakably fine taste and melts gently in your mouth.

160 years of passion have gone behind making some of the finest chocolates and creating new recipes. Lindt Gourmet Truffles have smooth melting centers enrobed in the finest Lindt chocolate and have been lovingly decorated. They have

been carefully selected and tastefully arranged to become a gift of chocolate that meets the most exacting demands.



How do you react to this marketing style? Yes, I know the answer! The evocative word "codswallop" comes to my mind (Wikipedia, if you need it). But how about jazzing up **your** publicity a bit? For example, for my own company JDI (JDIstruments), I plan to include in each shipment a card with the following words:

The people at JDI are true masters in the art of making vibrating wire instruments and they promote their craft with love and passion. They select high grade materials from only the best sources, such as Type 313 stainless steel or titanium, and machine them with great care.

In a facility called the "Assembly Benches", the metals and exquisite ingredients are

combined with soft O-rings and creamy lubricants - resulting in a tactile texture that can at once be felt by every connoisseur.

JDI offers an unrivalled range of instruments that satisfies all of your needs. They have an unmistakably fine performance and melt gently into your construction projects.

One year of passion has gone behind making some of the finest vibrating wire instruments and creating new products. JDI's vibrating wire instruments have smooth vibrating wires enrobed in the finest steels and have been lovingly decorated with JDI's logo. They have been carefully selected and tastefully manufactured to become instruments that meet the most exacting demands.

Closure

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

Sahetkon! (Lebanon)

Remote Monitoring of Loads in Rock Anchors – Process and Benefits

Ian Froggatt
Maurice O'Neill
Steven Turner

Project Background

The A55 Chester to Holyhead dual carriageway passes along the North Wales coast. Construction was carried out between May 1990 and April 1992. The route crossed diverse geological terrains and included two major rock

cuttings at Rhuallt Hill, the most significant being up to 27m deep and 1000m long. In the deepest part of this cut, side slopes are up to 80° in mudstones and siltstones of Silurian age. Dips at the eastern end of the cut were found to be up to 45°, directly

out of the face. Numerous bed shears comprising thin clay layers further complicated matters. Stabilization measures applied to the cut included 216 No. 1000kN capacity multistrand anchors up to 23m in length and 416 monobar anchors (Scott et al, 1997).

Ten of the original multistrand anchors were fitted with vibrating wire (vw) load cells which were then monitored. This article describes how these ten load cells were read manually until 2007, and then how eight of these cells were then subsequently read remotely (two cells were found to be faulty at the start of the remote monitoring period). The article explains how the remote monitoring system has greatly improved the speed, frequency and economy of the load cell monitoring process.

Manual Monitoring

At the end of construction of the cuttings in 1992, the following monitoring regime was recommended for the vw load cells (Scott et al, 1997):

1. Cells to be read fortnightly for the first 6 months.
2. Cells to be read monthly for months 7 to 12.
3. Provided anchor loads were being maintained, readings to be reduced to twice annually for the next 9 years.
4. After year 10, reading interval to be reduced to 5 years.

The regime described above indicates that 18 readings were to be collected for the first year after installation and 18 readings in total for the following 9 years.

In the last decade, the project owner’s reading regime for the vw load cells had been once every 20 to 40 days. To demonstrate the time period

between readings, Figure 1 shows data plotted for the period from July 1999 to February 2000. The red wavy line denotes ambient temperature.

Remote Monitoring System Installed in January 2008

Each load cell contains three vw transducers, equally spaced around the hollow annular load cell.

The core of the automated measurement system is a Campbell Scientific CR1000 datalogger, complemented with an AVW100 vw interface and an AM16/32 multiplexer. The CR1000 provides the control and measurement capability, activating the vw transducers and then measuring the frequency response. The AVW100 amplifies and filters the signals from the transducers. The AM16/32 multiplexer allows the system to switch between each of the 24 (8x3) transducers in turn. In addition, the battery voltage and local temperature are also monitored.

A GSM modem provides full telemetry, allowing for regular downloading of data, reprogramming and system management. The complete system is powered by a solar panel and battery system which is capable of maintaining monitoring for several weeks should the solar panel fail. In Figure 2 it can be seen that the system is mounted in a weatherproof enclosure on a 3m mast together with a high-gain aerial to ensure adequate signal strength to connect with the GSM network.

Monitoring with Remote Monitoring System

Following commissioning, the output was validated using the original calibration information to ensure continuity of the data. The recorded data are now down-loaded on a daily basis to a secure web portal where they can be viewed graphically using a standard web browser. If necessary, alarm levels can be implemented to warn of any unexpected changes in load.

Figure 3 shows data from the eight anchors which are being monitored remotely. The plot covers a period of time from March 2008 for more than one year, with anchor readings every six hours. The plot shows the average load derived using readings from the three transducers within the cells. During this time period, no visits to site were made while each transducer was read nearly 1,500 times, thus providing improvements in economy which speak for themselves. The lower, fluctuating line is the ambient temperature. This shows that the variation was from a high of approximately 27 °C in July to a low of approximately -6 °C in January. This enabled the project owner to see that load cell readings remained independent of seasonal temperature over this time.

Plots like Figure 3 are now e-mailed to the project owner on a regular basis. However, with the remote monitoring system, if the project owner wishes to

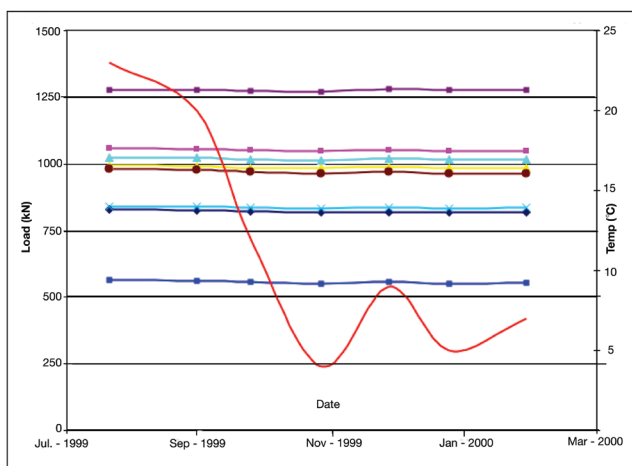


Figure 1. Load cell data collected manually.



Figure 2. Photograph of the equipment installed at Rhualt Hill cutting.

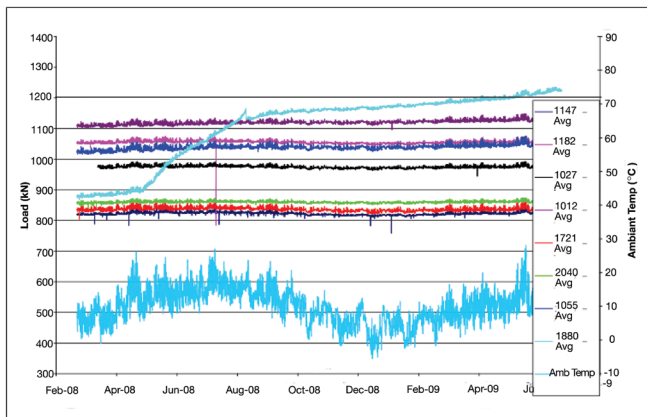


Figure 3. Graph showing data obtained via remote monitoring over a one year period.

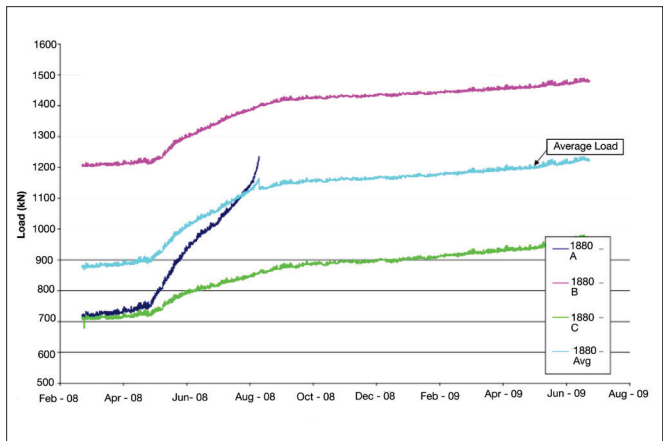


Figure 4. Remote monitoring data – Load cell 1880.

be more “hands on”, he can be provided with a password which will enable him to view his instrumentation system readings on-line at any time.

The remote monitoring system demonstrated its ability to provide early warnings when, as can be seen, in May 2008, one of the load cells (1880, shown in Figure 3 in light blue) began to show an apparent significant increase in load. The upward trend in reading was identified within days. The readings from this load cell are discussed further in the next section.

The “Failed” Transducer

The three vw transducers in each load cell are read separately by the remote monitoring system. One advantage of the remote system over manual readings is that it can be quickly and easily identified if any one individual transducer is failing. Figure 4 shows the individual readings from the three transducers within the load cell (No.1880) that showed an apparent significant increase in load. It can be seen that transducer ‘A’ was the one that was failing. This transducer was therefore removed from the data processing. The average load had been calculated using all three transducers up to August 2008 and then was calculated using only transducers ‘B’ and ‘C’. This explains why the reading “blips” downwards at this date. Taking this action meant that a single faulty transducer did not give rise to misleading readings. With manual readings, widely spaced in

time, it is much harder to identify the malfunction of a single transducer. The project owner is now paying particularly close attention to this load cell as the readings change.

Concluding Remarks – The Benefits of Remote Monitoring

Installation of remote monitoring equipment for the vw load cells on the Rhuallt Hill rock cutting has provided the project owner with the following benefits:

Greatly Improved Risk Management

With the ability to obtain readings of load in the rock anchors in almost real-time, a very early warning is provided of any load increases, or even of anchor failures. With the manual reading regime prior to installation of the remote monitoring equipment, it might have been weeks or months before it was possible to identify significant changes conclusively.

Improved Health and Safety for Monitoring Staff

Staff carrying out the monitoring no longer need to be exposed to the risks posed by traffic on the A55 road.

Vastly Reduced Cost per Reading

Prior to installation of the remote monitoring equipment, in order to obtain ten load cell readings, a site visit was required, followed by office work to process and present the data. For a single load cell, this would equate to

approximately £25 per reading. For the remote monitoring system, after the initial capital costs of the remote system have been taken into account (which were a few thousand pounds), the long-term cost per reading will drop to only a few pence. For a project owner who wishes to demonstrate that health and safety risks are being minimised, and who needs to examine the performance of his instrumentation with a much greater scrutiny than that afforded by manual readings, this represents excellent value for money.

Change in Reading Frequency at Virtually No Cost

With manual readings a doubling of the reading frequency implies a doubling of costs. With a remote monitoring reading system the project owner may increase and decrease the reading frequency at negligible impact on cost.

Reference

Scott M.J., Gordon T., Statham I., and Nichol D. Rock Anchor Stabilisation of Bedding Plane Shear Failures on the A55, Rhuallt Hill. (1997). In Ground Anchorages and Anchored Structures by G.S. Littlejohn. Inst. Civ. Engrs, London.

Ian Froggatt, Principal Engineer; Maurice O’Neill, Principal Engineer; Steven Turner, Engineering Geologist, Capita Symonds, Emerson House, Albert Street, Eccles M30 0TE, email: ian.froggatt@capita.co.uk