Instrumentation

John Dunnicliff

Introduction

This is the seventh episode of GIN. Several articles were well on track for the deadline, but eventually all missed it! Holidays, snow, workload, et al: all good reasons, but they don't get words on the printed page.

Instead of the promised articles you get a single recycled product, on the following pages, assembled just before the deadline. I hope that there are some worthwhile messages here, and that it isn't merely a page filler.

Continuing Education Courses

The two instrumentation courses, one in Florida and one in Vancouver, BC were held in late 1995. Attendance was between 35 and 40 at each. I can make several general observations:

- These were the first North American courses at which manufacturers made technical presentations. A significant plus: adds breadth and another perspective, provides details of some innovations, enhances the "we're all in this together" message.
- When manufacturers are involved, of course I have to invite many rather than a few, and a 2-day course, as in Vancouver, isn't long enough to include some of the topics that are needed in these courses. The 3-day Florida course was a better course.
- You can't please all of the people all of the time. Each person comes with a different need, and there isn't time to satisfy all those needs. The best that can be done is to structure the course so that everybody is "happy enough".
- In response to attendee requests, for future courses I'm going to consider an optional extra day, to include:
  - Topics requested by attendees during the main part of the course
  - Tricks of the trade (nuts and bolts details)
  - Detailed installation procedures for selected instruments (perhaps inclinometer casings and piezometers in boreholes)
  - Workshop on evaluation of data
  - Lessons learned from our mistakes
  - More time for questions and discussion

While at the course in Cocoa Beach, Florida we noticed that, almost wherever we went, there was background music: in the hotel lobby, bar and elevator, in restaurants, on the plane, in stores. There was even elevator music as background to the taped commentary by the head of NASA's Kennedy Space Center as we drove around in a tour bus! My vote is to do away with it all — are we becoming a society who needs this? Like chickens in a mass production facility for eggs — so we do our jobs better? I was reminded of a quip by Barrie Sellers (president of Geokon) who, when we taught numerous and repetitive instrumentation courses together, for Federal Highway Administration in the early 1980s, suggested that we might maintain our motivation by setting the course to music. The piezometer polka, the strain gage shuffle, the tamping hammer twist!

I'll announce future courses in GIN. The next course is planned for September 21 and 22, 1996, immediately before the 49th Canadian Geotechnical Society Annual Meeting and Conference in St. John's, Newfoundland. Preliminary details are given on page 44. The course will include presentations on instrumentation of offshore structures, by Elmo DiBiagio of the Norwegian Geotechnical Institute, which should be of particular interest to local geotechnical engineers. Unfortunately, there isn't time for an "extra day" because the only available time is a Saturday and a Sunday.

There are two other possibilities for future courses. First, there may be a course, focusing on instrumentation for rock, associated with the 36th U.S. Symposium on Rock Mechanics at Columbia University in New York, June 29-July 2, 1997. Second, the next course in Florida will be either late 1996 or late 1997: 1997 is more likely, because of concern for marketability only one year after the 1995 course.

Discussion Sessions at Professional Society Conferences

During 1995 I was involved with two discussion sessions on instrumentation, one at an ASCE convention and one during the 4th International Symposium on Field Measurements in Geomechanics (FMGM 95) in Bergamo, Italy. Despite playing a role in adopting a format, I don't think either was very successful. Both began with prepared presentations by about five panelists, 5-7 minutes each. The moderator then posed some questions in turn, and encouraged attendees and panelists to go from there. There are at least three problems with this format. First, the brief prepared presentations tend to be hurried and stiff. Second, because attendees see that panelists have had time to prepare, they tend to be reluctant to shoot from the hip and participate in a lively discussion. Third, when attendees take the floor, they often run off at the mouth on a different topic of their own choosing.

John Burland, Head of the Soil Mechanics Section at Imperial College of Science, Technology and Medicine in London, has suggested a better idea, which he has tried successfully. Appoint a "Grand Inquisitor" (this is the office of the courtly character Don Alhambra del Bolero in Gilbert and Sullivan's "The Gondoliers"). The only person who prepares is the GI. The GI opens the session by explaining the format, and putting a question or topic on an overhead viewgraph, asking one panelist "what do **you** think?" John reports that the discussions progress from there, are lively, involve all, can be kept on-topic by the GI, and continue in the bar afterwards. Let's try this sometime.

One other problem became evident during these discussions: audio arrangements are made so that the audience can hear the speaker. It is essential, if there is to be a discussion, that voices from the floor can be heard at the front, requiring not only a roving microphone but also a loud speaker directed towards the **front.**

Judgment and Sport

Jim Dette, ex Dames & Moore, wrote to me after reading GIN-6, commenting on the paragraphs headed "Judgment in Geotechnical Engineering," and saying "we need more of those types of reflections." He reminded me of the following wisdom of Karl Terzaghi; which Terzaghi gave to his students at Harvard as a set of rules for what he called the game of engineering:

1. *Engineering is a noble sport which calls for good sportsmanship. Occasional blundering is part of the game. Let it be your ambition to be the first one to discover and announce you blunders. If somebody else gets ahead of you, take it with a smile and thank him for his interest. Once you begin to feel tempted to deny your blunders in the face of reasonable evidence you have ceased to be a good sport. You are already a crank or a grouch.*
2. *The worst habit you can possibly acquire is to become uncritical towards your own concepts and at the same time skeptical towards those of others. Once you arrive at that state you are in the grip of senility, regardless of your age.*
3. *When you commit one of your ideas to print, emphasize every controversial aspect of your thesis which you can perceive. Thus you win the respect of your readers and are kept aware of the possibilities for further improvement. A departure from this rule is the safest way to wreck your reputation and to paralyze your mental activities.*
4. *Very few people are either so dumb or so dishonest that you could not learn anything from them.*

This quotation is included in an article by Ralph Peck entitled "Advice to a Young Engineer," which is reprinted in the book "Judgment in Geotechnical Engineering: The Professional Legacy of Ralph B. Peck" (page 204, for those who have the book).

Geomation, Inc. Training Courses

Dennis Gunderson of Geomation, Inc. has sent me the following information:

Geomation, Inc., manufactures and markets the System 2300 family of automatic Data Acquisition and Control Systems for harsh and remote environments. The System 2300 provides flexible solutions for a wide variety of geotechnical, environmental, and facilities monitoring and control applications. Geomation has recently introduced the 2380 Series of Measurement and Control Units (MCUs), and the new GEONET for Windows operating software.

To help customers fully utilize the capabilities of the System 2300 and particularly the new 2380 and GEONET for Windows software, periodic training courses are offered at their factory in Golden, Colorado. The next course will be held in early June. The course runs 4 days, and includes in-depth training in system operations, programming, and maintenance issues. Also included is an introduction to the graphical user software, Genesis, which provides a real time graphical user connection to GEONET.

The cost of the course, which includes a full set of training manuals, software upgrades to the latest version of GEONET and lunches for the 4 days is $800. Attendance is limited to 12 individuals to ensure a quality learning experience, and to allow opportunity for discussion among the students. Past attendees have found the shared experiences of users one of the highlights of the course. Please contact *Dennis Gunderson at Geomation, Inc., at 303-278-2350 (Phone), or 303-279-1029 (Fax)* for more information or to reserve a place.

Motivation

We haven't had any whimsical rhymes for a while. The last one was about the grouters' rallying call way back in June 1991. It's time for another.

At the recent Deep Foundations Institute annual meeting, George Goble was introduced by Bill Bermingham, who quoted Edgar A. Guest:

Somebody said that it couldn't be done,
But he with a chuckle replied
That "maybe it couldn't", but he would be one
Who wouldn't say so till he'd tried.
So he buckled right in with the trace of a grin
On his face. If he worried he hid it.
He started to sing as he tackled the thing
That couldn't be done, and he did it.
Someone scoffed: "Oh you'll never do that;
At least no one ever has done it";
But he took off his coat and he took off his hat,
And the first thing he knew he'd begun it.
With a lift of his chin and a bit of a grin,
Without any doubting or quiddit,
He started to sing as he tackled the thing
That couldn't be done, and he did it.
There are thousands to tell you it cannot be done,
There are thousands to prophesy failure;
There are thousands to point out to you, one by one,
The dangers that wait to assail you.
But just buckle in with a bit of a grin,
Just take off your coat and go to it;
Just start to sing as you tackle the thing
That "cannot be done", and you'll do it.

Good stuff! I'm sure there are some applications to geotechnical instrumentation.

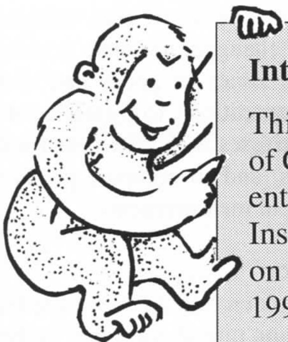
Closure

To those of you who have written to say that you like this column: thank you for going out of your way to say so. I sometimes wonder whether the column and editorial task is worth all the effort, but if some of you like it, that makes the effort worthwhile.

Please send contributions to this column, or a separate article for GIN, to me: *16 Whitridge Road, South Natick, MA 01760. Tel. (508)655-1775, fax (508)655-1840.* Kasugta! (Greenland)

Some Instrumentation Problems and Solutions

John Dunnicliff



Introduction

This article is a recycled product. It is based on part of a paper "The Practical Use of Geotechnical Instrumentation: Some Problems and Solutions," prepared for presentation as the Keynote Lecture for Session 2, "Problems Related to the Use of Instrumentation and Monitoring Systems," during the 4th International Symposium on Field Measurements in Geomechanics (FMGM 95), Bergamo, Italy, April 11, 1995.

The recycled product includes some text and figures with a light-hearted flavor — something an author can get away with in a magazine article but not in a formal paper!

PROBLEM 1. The Golden Rule

The Problem

The golden rule is:

Every instrument on a project should be selected and placed to assist with answering a specific question: if there is no question, there should be no instrumentation.

We all know this. The problem is that we sometimes disobey the rule.

An Example

I used to work with a consulting engineering company, often providing instrumentation services to construction contractors. We signed a subcontract, with the prime contractor, to furnish and install instrumentation in two underground subway stations in rock. The specification called for vibrating wire strain gages to be installed on every eleventh rib, 16 per rib, back-to-back as shown on Figure 1, together with 42 multi-point borehole extensometers at approximately equal spacing along the excavations. The subcontract price was about US $600,000.

I wondered what this was all for, and suggested a meeting to find out, in an attempt to make the effort as cost effective as possible. About 20 people sat down for the meeting — the owner, the construction manager, the designer, the prime contractor, the instrumentation subcontractor. After explaining the reason for the meeting, the conversation went something like this:

Subcontractor.

"So, can someone tell me what is the purpose of the instrumentation program?"

Silence.

Subcontractor.

"Please, ***somebody*** *must know."*

More silence.

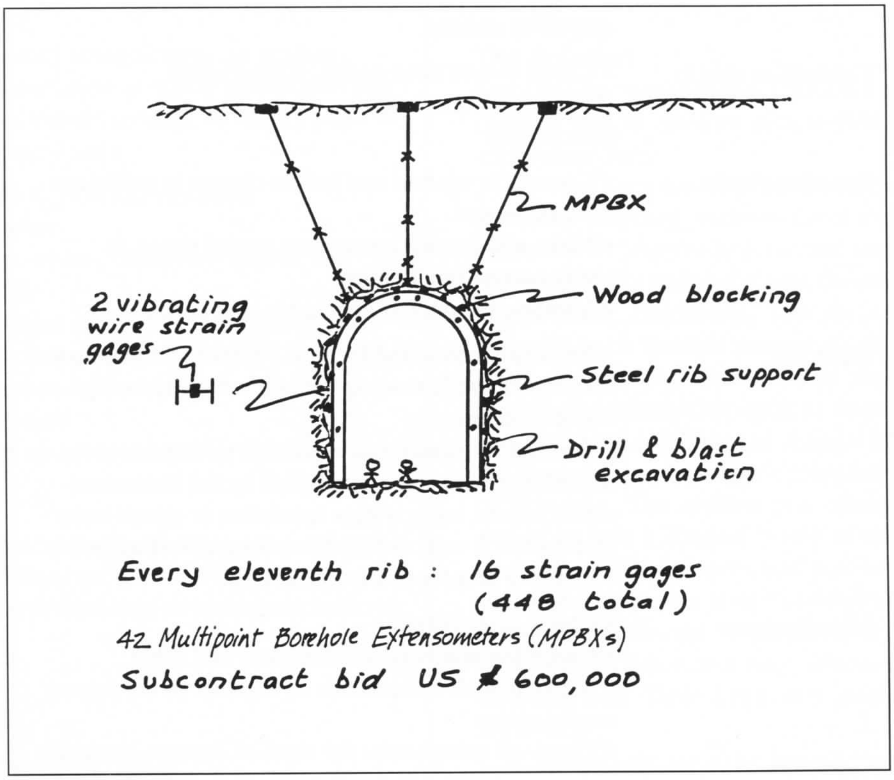


Figure 1. Subway station in rock

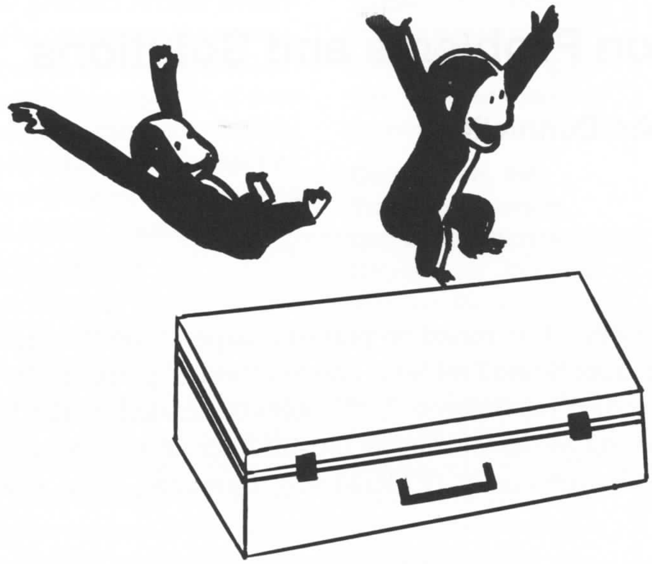


Figure 2. Instrumentation shipped by air freight

TABLE 1. Possible Items in Pre-installation Acceptance Tests

Category	Item
Data supplied by manufacturer	✓Examine factory calibration curve and tabulated data, to verify completeness ✓Examine manufacturer's final quality assurance inspection check list, to verify completeness
Documentation	✓Check, by comparing with procurement document, that model, dimensions, and materials are correct ✓Check that quantities received correspond to quantities ordered
Calibration checks	✓Check two or three points, if practicable ✓Check zero reading, e.g. of vibrating wire piezometers
Function checks	✓Connect to readout and induce change in parameter to be measured ✓Make and remake connectors several times, to verify correct functioning ✓Immerse in water, if applicable, and check
Electrical	✓Bend cable back and forth, at point of connection to instrument, while reading the instrument, to verify connection integrity ✓Perform resistance and insulation testing, in accordance with criteria provided by the instrument manufacturer, using a gage insulation or circuit tester that applies 2 volts or less for resistance testing and 15 volts or less for insulation testing
Miscellaneous	✓Check cable length ✓Check tag numbers on instrument and cable ✓Verify that all components fit together in the correct configuration ✓Check all components for signs of damage in transit

Subcontractor.

Catching eye of designer. "Surely..."

Designer.

"Okay, why don't you write us a memo to suggest what the purpose might be?"

I kid you not! The memo was written, the program changed, to create several instrumented zones in good, bad and typical rock conditions, to correlate calculated rib stresses with measured rock deformations, and to compare predictions with field measurements.

The Solution

Follow the golden rule. In the example, a valid question turned out to be "Is the rib size unnecessarily conservative?"

PROBLEM 2. Installing Instruments That Don't Work

The Problem

If an instrument is not working perfectly before installation, there's not much hope of it working well after installation.

An Example

A manufacturer had a comprehensive quality assurance program, and performed extensive factory calibrations. Despite careful packing before shipment to the user by air freight, the instrument was faulty when unpacked at the site, and installed without detecting the fault. Figure 2 (with acknowledgement to Curious George and also to an old Samsonite ad) shows why. Have you seen freight being handled at O'Hare airport?

The Solution

The user should perform "pre-installation acceptance tests," possibly including the items listed in Table 1.

PROBLEM 3. Going into the Field Unprepared

The Problem

Manufacturers' instruction manuals usually provide good descriptions of how to use and maintain the instruments, and most contain guidelines on installation. However, if the installation

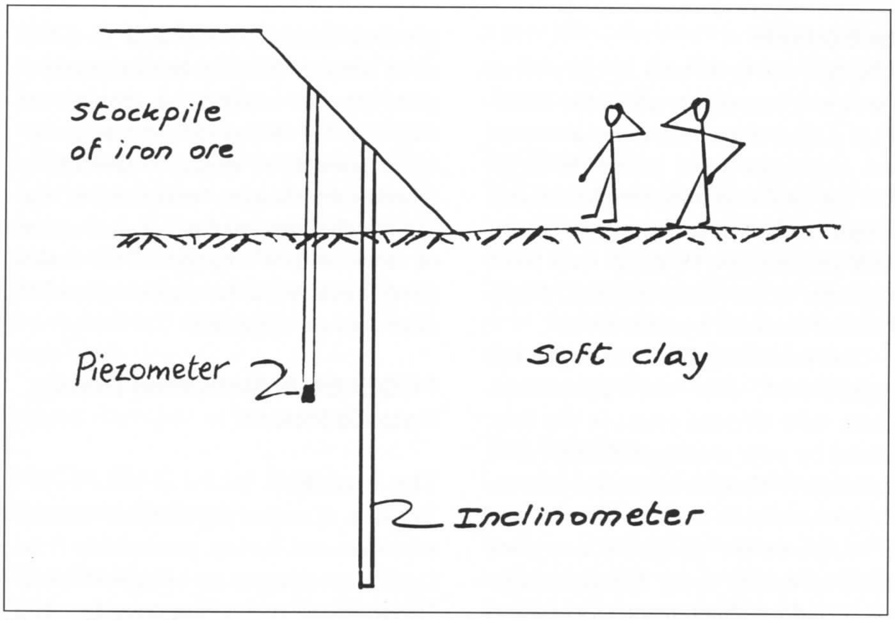


Figure 3. Installing instruments to monitor an embankment on soft ground

TABLE 2. Possible Content of Installation Record Sheets

Category	Content
Heading	✓Project name ✓Instrument type and number, including readout unit ✓Personnel responsible for installation ✓Date and time of start and completion
Planned data	✓Planned location in plan and elevation ✓Planned orientation ✓Planned lengths, widths, diameters, depths, and volumes of backfill ✓Spaces for necessary measurements or readings required during installation to ensure that all previous steps have been followed correctly, including post-installation acceptance tests
As-built data	✓As-built location in plan and elevation ✓As-built orientation ✓As-built lengths, widths, diameters, depths, and volumes of backfill ✓Plant and equipment used, including diameter and depth of any drill casing used ✓A log of appropriate subsurface data ✓Type of backfill used ✓Post-installation acceptance test
Weather	✓Weather conditions
Notes	✓A space for notes, including problems encountered, delays, unusual features of the installation, and any events that may have a bearing on instrument behavior

procedure depends on specific site conditions, such as subsurface stratigraphy, local drilling customs, experience of installers, or deformations that are likely to occur after installation, the manufacturer cannot be expected to provide detailed installation procedures. If the installer goes into the field without planning details of the installation procedure, there will be problems.

Although manufacturers' manuals are able to describe data collection, processing and plotting procedures more readily than installation procedures, they are not always applicable to every site.

An Example

Figure 3 shows a two-person crew who are to install inclinometers and vibrating wire piezometers for monitoring an embankment on soft ground. They have read the manufacturer's manual, and start installation work. The open borehole in soft clay won't stay open, and inclinometer casing becomes stuck part way. Bentonite seals for the piezometers hang up in the borehole. A piezometer cable is cut, and the crew doesn't have a splice kit. The drill rig stands by, billing by the hour, while the crew goes back to the drawing board.

The Solution

Installation procedures should be planned well in advance of scheduled installation dates.

Written step-by-step procedures should be prepared, making use of the manufacturer's instruction manual and the installer's knowledge of specific site geotechnical conditions. The procedures must be flexible enough to account for unexpected conditions that arise during installation, such as unexpected ground conditions or changes in the construction contractor's procedure or schedule. The written procedures should include a detailed listing of required materials and tools, and post-installation acceptance tests. Installation record sheets should be prepared, for documenting factors that may influence measured data. Table 2 indicates possible content.

If instruments are to be installed by the owner's personnel, these procedures will be used directly. If they are to be installed by the construction contractor, an abbreviated version will be included in the specifications, retaining key items for enforcement by the owner's representative, and the procedures will be used when reviewing the contractor's submittal of proposed installation methods.

Site-specific written step-by-step procedures are also worthwhile for data collection, processing and plotting, and will also be based on the manufacturer's manual and on knowledge of specific site conditions.

PROBLEM 4. Allowing Dust to Grow on Data

The Problem

Very great effort can sometimes be made to install instruments and collect data, but then data are filed away until some later time when "I'll look at the data and do the interpretation." What happens when, months or years later, the file drawers are opened and the data don't make sense?

An Example

A bridge was to be built across a river. There was uncertainty about the stability of a talus slope behind one abutment and, about two years before the target date for finalizing abutment foundation design, inclinometer casings were installed in the slope. Readings were taken regularly, by university students. Many different students were involved.

Data were filed. When the target date approached, data were examined. There were obvious errors in the data, caused by poor reading and calibration techniques. Despite extensive efforts, no sense could be made of the data, and a "no movement" judgment was made based on eyeing along a straight highway guard rail that ran across the slope.

Perhaps this example could be used to argue that the inclinometer casings were unnecessary, but that isn't my point!

The Solution

Data should be reviewed on an ongoing basis. The first step is to compare measured data with previous data. Second, if significant changes are noted, the measurement should be repeated to determine whether there has been a measurement error or whether the changes are real. Third, if changes are real, an evaluation should be made to determine whether the changes "make sense," i.e. can they be correlated with construction or other "causal" changes? This evaluation should be made as soon as possible after data are collected.

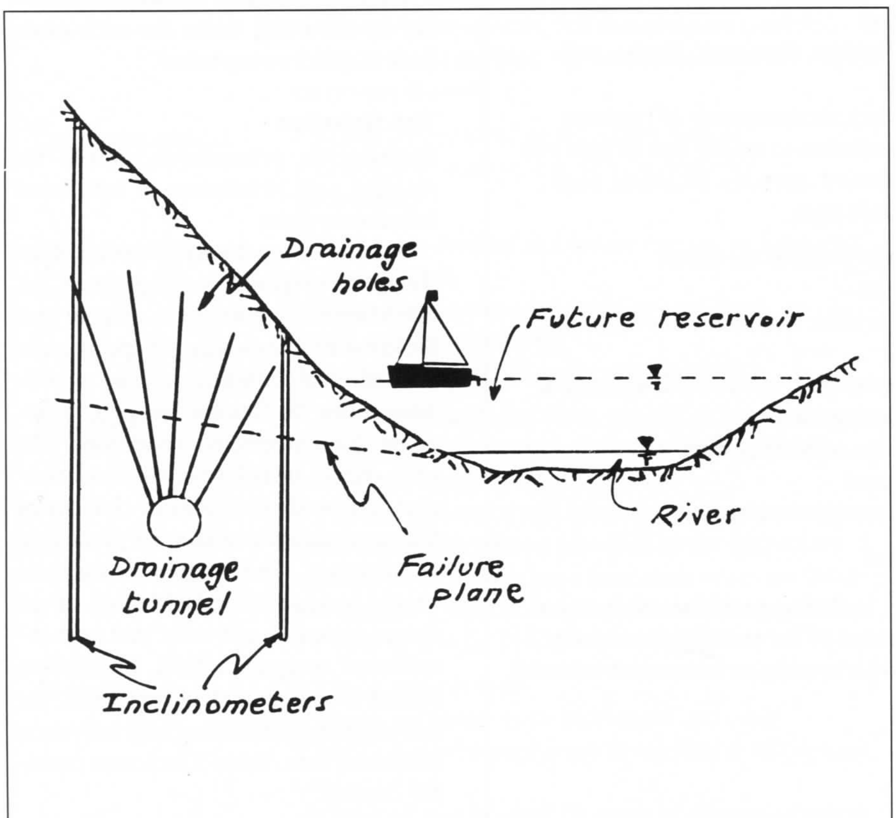


Figure 4. Landslide stabilization

PROBLEM 5. Motivation During Data Collection

The Problem

The task of collecting data can become repetitive and boring, particularly if no significant changes are being measured. Hence there is a temptation for data collection personnel to be less thorough than they should, and there are several reported cases of personnel "inventing data" while keeping warm in a nearby coffee shop!

An Example

Construction of a dam had been completed. While excavating for a new road above the future reservoir level, there were indications of ground movement in the hillside. There were concerns for massive landslides which, if allowed to occur after the reservoir was filled, might cause a wave to overtop the dam. Steps were therefore taken to stabilize the slopes, by constructing drainage tunnels and drainage holes. Inclinometers and piezometers were installed to monitor the slopes during staged and slow reservoir filling (Figure 4. Somebody tell the helmsman to tack!).

Instrumentation was read daily, requiring several crews, working for many months. The "hope" was that no movement would occur, therefore the crews didn't have much to excite them during their day. A possible "natural" for the coffee shop syndrome?

The Solution

Personnel who understand the significance of their tasks are likely to have greater motivation than those who do not. Two specific steps can be taken to maximize motivation. First, at the beginning of the project, meet with all data collection personnel to explain what their task is to be, why it is important, and how it fits in with "the big picture." Second, on a regular basis, perhaps weekly or monthly, meet with them again to explain "what happened" : how their work product was used to benefit the project. If these two steps are taken, data collection personnel are likely to feel a sense of involvement and importance, hence to maximize the quality of their work.

These two steps were taken for the project described in the example.

PROBLEM 6. Lump Sum Payment Method

The Problem

When procurement of instrumentation materials and field services are included in a construction contract, a lump sum payment method is often favored by owners and design project managers. However, with geotechnical instrumentation work, numerous changes usually occur in the field, including instrument quantities, drilling depths and reading schedules. Determination of equitable price adjustments to a lump sum bid is a very laborious process, often resulting in the owner paying more than the change is worth.

An Example

The owner and design manager for a large multi-contract highway project insisted on a lump sum payment method for instrumentation. The resident engineer found that, when inevitable changes occurred in the field, price adjustment required an excessive effort.

The Solution

Use a unit price payment method: this is much more flexible than a lump sum method. Possible unit price items are included in Table 3. For the project described in the example. The resident engineer put forward the advantages of a unit price schedule, and convinced decision-makers to adopt such a schedule for future contracts.

TABLE 3. Possible Unit Price Payment Items

Item	Unit	Comments
Furnish... readout unit	Each	✓One item for each instrument type. Includes factory calibrations
Furnish and install...	Linear foot for borehole instruments. Each for others	✓One item for each instrument type. Includes all materials left in place, labor, tools and equipment, drilling, sampling, installation, installation of surface protection, and determination of as-built location
Read...and report data	Each	✓One item for each instrument type. Need to specify exactly what is meant by one reading. Includes reading; data reduction, processing, presentation, reporting; regular field calibration and maintenance; repair
General geotechnical instrumentation requirements	Lump sum	✓Includes repairing or replacing damaged instruments, furnishing specified submittals, interpreting data, all other items of work for which no separate bid item is provided

Closure

Peck (1972) wrote:

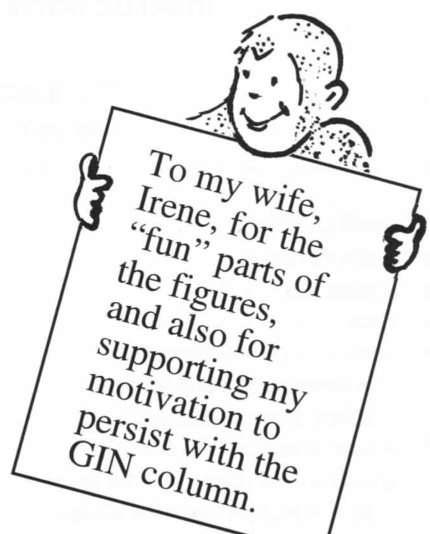
Field observations provide a powerful and sometimes indispensable tool in applied soil mechanics. It concerns me that the legitimate use of instrumentation may be set back by a rising tide of disillusionment on the part of those who have been persuaded to embark on elaborate programs that promise too much. It concerns me that too many programs are based on the number of instruments to be used rather than on the questions to be answered. It concerns me that sophistication and automation are substituted for patient proof testing of equipment under field conditions. To the extent that such practices prevail, they must be discouraged so that the observational approach itself will not be discredited. We need to carry out a vast amount of observational work, but what we do should be done for a purpose and done well.

That advice is just as applicable today as it was nearly 25 years ago. The contents of this article are an attempt to help practitioners to "do it well."

Reference

Peck, R. B. (1972), "Observation and Instrumentation: Some Elementary Considerations," Highway Focus, U.S. Department of Transportation, Federal Highway Administration, Vol. 4, No. 2, pp. 1—5, Reprinted in Judgment in Geotechnical Engineering: The Professional Legacy of Ralph B. Peck (1984), J. Dunnicliff and D. U. Deere (Eds.), Wiley, New York, pp. 128—130.

Acknowledgment



Geotechnical Instrumentation for Field Measurements

2-Day Course with John Dunnicliff & Elmo DiBiagio

September 21-22, 1996 Hotel Newfoundland, St. John's, Newfoundland

(Immediately preceeding the 49th. Canadian Geotechnical Society Annual Meeting and Conference)

Course Sponsored by:

Geotechnical News
in association with
St. John's Geotechnical Society

Course Emphasis:

This is a course for practitioners, taught by practitioners. The emphasis is on "why and how". The topic is instrumentation for monitoring performance during construction and operation rather than instrumentation to determine insitu parameters. A significant part of the course will focus on instrumentation of offshore structures.

Why You Should Attend:

- To learn the who, why and how of successful geotechnical monitoring
- To ensure that your monitoring programs are tailored to match your specific geotechnical questions
- To avoid the common problem of poor quality data

Who Should Attend:

- Engineers, geologists, or technicians who are involved with performance monitoring of geotechnical features during construction and operating phases
- Project managers and other decision makers who are concerned with safety or performance of geotechnical construction and consequential behaviour
- People who are or will be working on the design and/or construction of offshore structures

Textbook Included

Geotechnical Instrumentation for Monitoring Field Performance, by John Dunnicliff by Wiley in 1988, will be part of the course materials.

Topics to be Presented by John Dunnicliff

- Overview of hardware for measuring groundwater pressure, deformation, load and strain in structural members, and total stress in soil
- Instrumentation for various types of projects, selected by attendees from the following list:
  - Braced excavations
  - Embankment dams
  - Excavated and natural slopes
  - Underground excavations
  - Driven piles
  - Drilled shafts

  There should be time for four of these project types.
- Systematic approach to planning monitoring programs
- Workshop on planning a monitoring program: embankment on soft ground

Topics to be Presented by Elmo DiBiagio

- Offshore instrumentation
  - Past
  - Present
  - Future

Cost

$699.00 CDN/$530.00 US with Dunnicliff's book "Geotechnical Instrumentation for Monitoring Field Performance". If an attendee already owns the book, cost will be $621.00 CDN/$470.00 US.

For more information or to register, contact:

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- Date
- Sponsoring Professor and University (contact address, telephone number, etc.)
- A brief abstract (300 words) (preferably on disk, or email to BiTech_Publishers@mindlink.bc.ca).

  If using email, please encode using Binhex.

[NOTE: If the promised Windows 95 Network works, we should be able to receive files by that method by next year.]

We need:

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- Copy of Title Page of Thesis

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