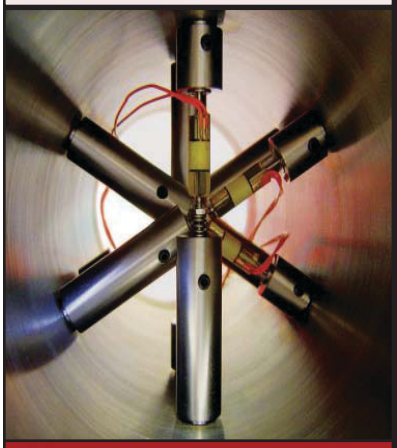

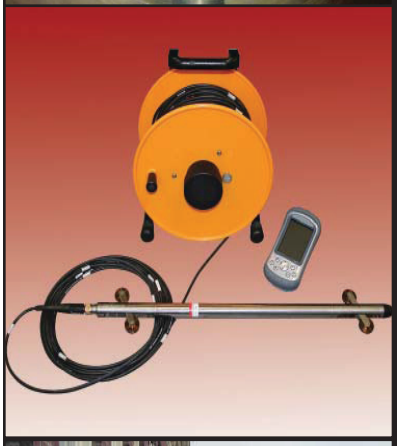

The University of Florida

Geotechnical Instrumentation for Field Measurements

April 3-5, 2011

Doubletree Hotel • Cocoa Beach, Florida

Course Director: John Dunnicliff
Lectures by Users of Instrumentation
Lectures and Displays
by Manufacturers of Instrumentation

COURSE EMPHASIS: The emphasis is on why and how, and will be updated to include web-based monitoring, wireless monitoring, emerging technologies and online sources of information. Prior to the course, registrants may submit questions and requested discussion topics, and a half day has been assigned for responding to these requests.

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

WHY: To learn the who, why, and how of successful geotechnical monitoring. To meet and discuss with others in the geotechnical instrumentation community.

WHAT: Practical information by leaders of the geotechnical instrumentation community, respresenting both users and manufacturers:

- John Dunnicliff, Consulting Engineer
- Martin Beth, Sol Data
- Aaron Grosser, Barr Engineering
- Daniele Inaudi, Roctest/Smartec
- Allen Marr, Geocomp
- Justin Nettle, Federal Energy Regulatory Commission
- Tony Simmonds, Geokon
- Robert Taylor, RST Instruments

For full details visit:
www.conferences.dce.ufl.edu/geotech

Geotechnical Instrumentation NEWS

Geotechnical Instrumentation News

John Dunnicliff

Introduction

This is the sixty-fifth episode of GIN. One full article and six one-pagers this time.

Converting Strain Measured in Concrete to Stress

This is a topic that has fascinated and puzzled me for a long time. Unlike for steel, the relationship between strain and stress in concrete is by no means straightforward because so many factors, other than stress change, cause strain. I struggled with guidelines when writing the red book (Sections13.3.9 and 13.4.7) but have never felt that they were adequate. Here's an article by Roberto Acerbis and his colleagues in Italy and Australia, which does a far better job than I did.

Web-based Data Management Software

David Cook's article "Fundamentals of Instrumentation Geotechnical Database Management – Things to Consider" was in the previous GIN (December 2010). As said in my previous column, I sent the article to several firms who supply web-based data management software, inviting each to respond with a one-page "Ours will do this" article. Here are those one-pagers, without any editing by me.

I thought that I'd invited all firms who supply web-based data management software, but I goofed—others have pointed that out. There's an ad on page 33 by SolData, whose "GEOSCOPE" is a fullweb and GIS software hub for geotechnical, structural and environmental real-time data.

Next Instrumentation Course in Florida

Dates are now April 3-5, 2011 at Cocoa Beach. Details are on page 28 and on http://conferences.dce.ufl.edu/geotech.

Next International Symposium on Field Measurements in Geomechanics (FMGM)

As many of you will know, FMGM symposia are organized every four years, the previous one being in Boston in September 2007. They are "the places to be" for folks in our club. The next FMGM will be in Berlin, Germany on September 12-16, 2011. Information is on www.fmgm2011.org.

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.

Wen Lie! (China).

Recommendations for Converting Strain Measured in Concrete to Stress

Roberto Acerbis
Harry Asche
Guido Barbieri
Tiziano Collotta

Introduction

Geotechnical engineering involves uncertainties, arising from simplifications which are necessary during the design phase, primarily due to limited information about the soil properties and behaviour. It is important to monitor the performance of structures during the construction phase, to compare the actual loads and stresses with those anticipated during design. For concrete structures,

strain gauges can be installed inside the structure during casting in order to directly record the strain state during different construction phases. From these measurements, stresses and internal forces can then be derived. To obtain reliable estimates of the forces and stresses, one must use correct assumptions about concrete behaviour as well as a proper conversion procedure. The creep behaviour of concrete, shrinkage and hardening should all be considered to avoid macroscopic errors. This is particularly true with regard to concrete structures which undergo loads only a few days after casting, such as temporary supports, tunnel linings or pier foundations. In the following, a conversion procedure aimed to properly simulate concrete behaviour is described and its application to real monitoring cases is presented. We show the effect of each strain contribution and the errors which could result as a consequence of following too simplified a conversion procedure.

General Description of Strain Gauges and Their Installation Procedure

Strain gauges are the most commonly used instruments for measuring strains, and consequently for determination of stresses in concrete structures. As a possible alternative, fibre optic systems have been developing during the last decade. These are able to provide extensive information, but are considerably more expensive than other methods, and hence are usually only used for special applications. A strain gauge measures, by means of a vibrating wire or resistive sensor, the relative displacement between two supports that are fixed to the structure and orientated parallel to the instrument. The strain gauge has to be installed with its main axis parallel to the direction of the strain (with its consequent stress) to be measured. In order to derive axial force and bending moment of a structural element, strain gauges have to be installed parallel to the longitudinal axis of the structural element and at least two should be installed: one at the extrados and a second at the intrados. In plain concrete structures, strain gauges are embedded within the concrete during casting, whereas in reinforced concrete elements they are usually welded or glued to reinforcement bars (see Figure 1a, 1b). The sensor records the deformation electronically, hence it is possible to connect the instrument to a data acquisition system so as to record data and to undertake real-time monitoring. Strain gauges are usually equipped with a thermal sensor in order to record the surrounding temperature during the readings and to estimate the contribution of thermal strain to the structural element.

During installation, it is important to take some precautions to obtain accurate and reliable results:

- Protect strain gauges by a proper shield to avoid possible damages during concreting due to the concrete flow or concrete vibrators; this can be achieved by placing a polystyrene casing around the gauge, if welded gauges are used, or a steel sheet around the sensor when placing embedded gauges;
- Protect cables by PVC pipes to avoid potential damage during the different construction phases;
- Verify operation of each instrument by taking a first reading before casting, to allow for replacement of malfunctioning strain gauges;
- Perform a data acquisition immediately after wiring so as to verify operation of the data acquisition system.

Conversion Procedure

Assumptions

As previously stated, in order to obtain reliable information about stresses within the structure, a proper conversion procedure should be adopted to obtain stresses from measured strains.

As first step, if the instrument is not thermally self-compensated, as it is the case for vibrating wire gauges, a correction must be applied to the readings. A procedure will usually be described by the instrument manufacturer, in order to compensate readings for the thermal errors in the gauge itself (as opposed to the effect that temperature has on the strain in the concrete or steel). If resistive sensors are used instead, they are usually self-compensated by the Wheatstone bridge system.

Once the total strain (corrected for thermal errors in the gauge itself) is measured, various concrete strain components have to be considered, in addition to instantaneous strain due to stress increments, in order to take into account the complex behaviour of concrete. Thermal (concrete and steel) strain, shrinkage and creep strain should all be considered. Moreover, the effect of variations in the Young's modulus of concrete during the hardening process has to be assessed with regard to the relationship between elastic strain and stresses. A proper estimation of such contributions is critical to understanding the strain behaviour of concrete structures, particularly if the

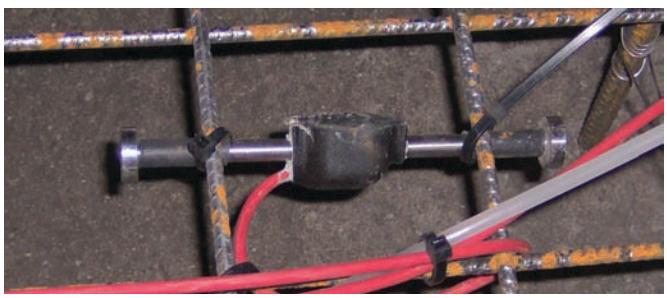

Figure 1a. Strain gage welded to steel bar.

Figure 1b. Strain gage embedded in concrete.

structure undergoes loading immediately after casting (see Collotta *et al* [2010]).

In the following, the proposed conversion procedure is described, based on the following assumptions:

- There is perfect bonding of the steel bars to surrounding concrete;
- The strain distribution is linear within the monitored section (according to traditional beam theory);
- The concrete is linear elastic, but with a tension cut-off (at the average concrete tensile strength);
- The variation of Young's modulus with time, the creep coefficients and the development of shrinkage strain follows the rules proposed in the CEB-FIB Model Code 1990 (Comité Euro-International du Béton [CEB], 1991);
- The monitored cross-section undergoes axial force and bending moment around an axis orthogonal to the virtual line passing through the two strain gauges.

Procedure

In the following formulas, subscript "*i*" means that the quantity is computed at the time of measurement t_i. At all times, correcting for the gauge thermal error, the total strain at time t_i is $\varepsilon_{tot,i}$, being the difference between the measured strain at the gauge and the initial measurement. On the basis of the assumption of a linear strain distribution, the total strain at any given point along the cross-section is derived from the total strain at the two measuring points within the monitored cross-section. Thus the strain can be computed at the extreme fibres of the concrete section as well as at the positions of the reinforcing bars. Assuming perfect bonding, the corrected measured strain is assumed to apply both to the concrete and the steel.

The stress in the steel bars can then be easily derived in each measuring instant by the computed total strain ($\varepsilon^s_{tot,i}$), taking into account the thermal contribution:

$$\sigma_{s,i} = \left(\varepsilon^s_{tot,i} - \left(T_i - T_0\right)\cdot \alpha_s\right)\cdot E_s$$

where T_i and T_0 are respectively the measured temperature at instant t_0 and instant t_i, E_s is the steel Young's modulus (210 GPa) and α_s is the steel thermal coefficient.

As for the computation of concrete stress in any given point in the cross-section, a step-by-step procedure has been adopted (see Ghali A. *et al* [2002]), so as to properly take into account the contribution of shrinkage and creep strains and the effects of Young's modulus variations over time. Knowing the corrected total strain at a certain point on the section, from t_0 to t_i, the concrete stress at the same point in each interval between consecutive measurements is obtained using the following formula, as a function of the total strain at all the previous measuring instants:

$$\Delta\sigma^c_{i-\frac{1}{2}} = \frac{E^c_{i-\frac{1}{2}}}{1+\varphi_{i,i-\frac{1}{2}}}\left(\varepsilon^c_{tot,i} - \varepsilon_{cs,i} - A_{i-1}\right)$$

where $\varepsilon_{cs,i}$ is the shrinkage strain at instant t_i, $\varphi_{i,j}$ is the creep coefficient between instants t_j and t_i and $E_{c,i}$ is the concrete Young's modulus at instant t_i and A_{i-1} is a function of the previous load steps as follows:

$$A_{i-1} = \sum_{j=1}^{i-1}\left(\Delta\sigma^c_j \frac{1+\varphi_{i,j}}{E^c_j}\right)$$

The curves of such quantities versus time can be obtained from National codes, Eurocodes or other relevant codes. In this case, we have adopted the suggestions given by CEB-FIP Model Code 1990 (Comité Euro-International du Béton [CEB], 1991).

Having derived the stresses in the reinforcement and in the concrete section borders for each time of measurement, it is possible to verify whether the concrete section cracks. If it does not, i.e. if it is completely compressed or if the maximum computed stress in the concrete is lower than its tensile resistance, the whole concrete section has to be considered in the calculations. Otherwise, the effective concrete section has to be calculated at each instant by computing at what height the concrete stress reaches its mean tensile resistance. Then, by integrating the forces over the effective section, internal actions (axial force and bending moment), can be derived.

Application to Real Structures

The proposed procedure is applicable in every case where performance monitoring of concrete structures is required. In the following section, the results obtained from two different applications are presented: first, a concrete ring beam support for a shaft excavation; second, the permanent lining of a highway tunnel. Both examples are derived from a large construction site for the development of a new highway route between Bologna and Florence in the central part of Italy.

In the first case, the reinforced concrete ring beam was cast after excavating down to the ring beam location. Further excavation of the shaft transfers the force to the ring beam. To counterbalance the radial thrust acting all over its circumference, a compressive axial force develops; gauges have been installed to compare the actual values of the axial force to the design assumptions and to check for unexpected bending moments due to unsymmetrical thrusts or geometric imperfections. The ring beam is thus loaded just one or two days after casting, when hardening is still taking place.

In the second case (the Buttoli tunnel), the permanent lining is cast all around the tunnel boundary, usually in two or more pours (first, the invert and, then, the crown) in order to sustain part of the soil pressure in the short-term and all of it in the long-term. Moreover it is designed to protect the tunnel inner space from humidity and possible water ingress. The gauges have been installed to measure the actual values of axial force and bending moments acting on the lining both in the short and in the long term. During tunnelling, the excavation continues immediately after the casting of the concrete and therefore the initial loading of the concrete occurs just after the casting.

In order to estimate the axial force and possible bending moments in the annular beam, four instrumented sections are provided, each formed by a two strain gauges, located one at the

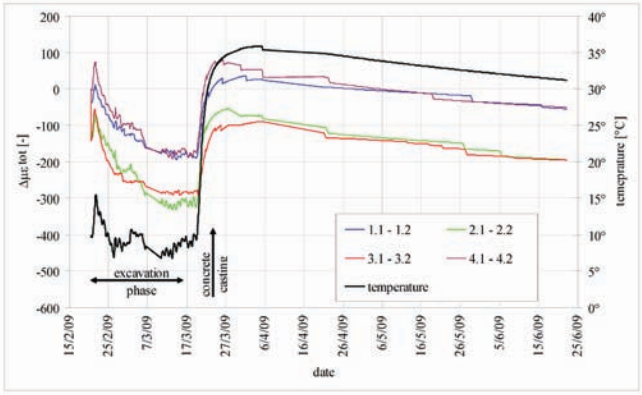

Figure 2a. Ring beam - Measured in strain vs time.

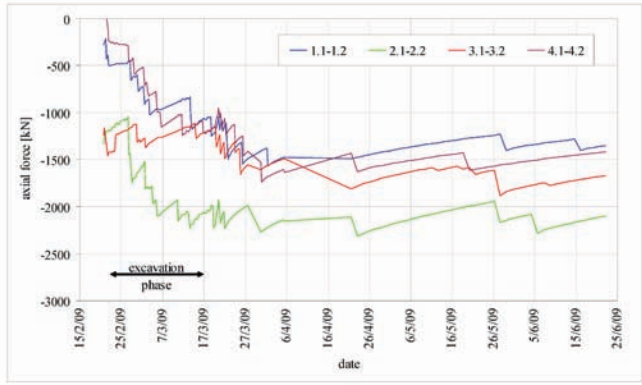

Figure 2b. Ring beam – Computed axial force vs time.

intrados and one at the extrados in circumferential direction. The four sections are equally spaced around the ring circumference. In order to estimate axial force and bending moment in the permanent lining of the Buttoli tunnel, a cross section was provided with five pairs of strain gauges, equally distributed along the lining: a pair for each side, one at the crown and other two intermediate points. The invert was not instrumented. In both the example cases, the strain gauges were welded to steel bars.

In the following figures, the corrected measured total strains, averaged in each instrumented section between extrados and intrados, and the corresponding axial forces, computed by the proposed procedure, are shown for both the ring beam (*Figure 2*a, 2b) and the tunnelling example (*Figure 3*a, 3b). Each curve refers to a pair of strain gauges; as for the tunnelling example, 1.1-1.2 and 5.1-5.2 correspond to the pairs of strain gauges placed on the left and right sides of the tunnel lining, 3.1-3.2 to the one placed at the crown and the remaining ones to the two intermediate points. In the total strain versus time figures, temperature inside the concrete is also plotted. In *Figure 2*a, the effect of the temperature rise due to concrete casting on the strain values is clear, whereas, in a similar way, the effect of seasonal temperature variation on the concrete strain can be seen in *Figure 3*a. The maximum values of axial force derived by the measurements turned out to be in both case studies within the design values: in the first case, the measured value is almost 70 % of the design one, whereas in the second case the maximum measured value is equal to 65% of the design value. Such differences can be explained by precautionary assumptions adopted in the design phase.

The importance of applying the correct conversion procedure is shown in Tables 1 and 2. For each of the two considered examples, the final axial forces computed by the proposed procedure (N1) are compared to the ones derived by disregarding respectively:

- N2: shrinkage and aging (i.e. changing Young's modulus with time);
- N3: creep and aging;
- N4: creep and shrinkage;
- N5: considering concrete as simply an elastic material (i.e. disregarding all time-dependent effects).

As is clear by comparison between N1 and N5, if the conversion procedure is too simplified, the stresses can be overestimated by a factor of nearly six.

Conclusions

In order to obtain reliable estimates of stress by installing strain gauges embedded in concrete structures or welded to reinforcement bars, a proper conversion procedure must be adopted. The proposed procedure takes into account the complex behaviour of concrete by considering the effect of shrinkage, creep strain and hardening. Such a procedure can be easily implemented by an Excel spreadsheet and a Visual Basic routine. As shown by the examples, the proposed procedure leads to results that can be compared to the design estimations, whereas adopting too simplified a

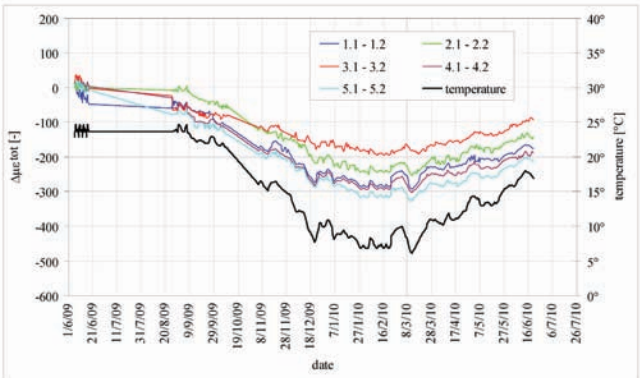

Figure 3a. Tunnel lining – Measured strain vs time.

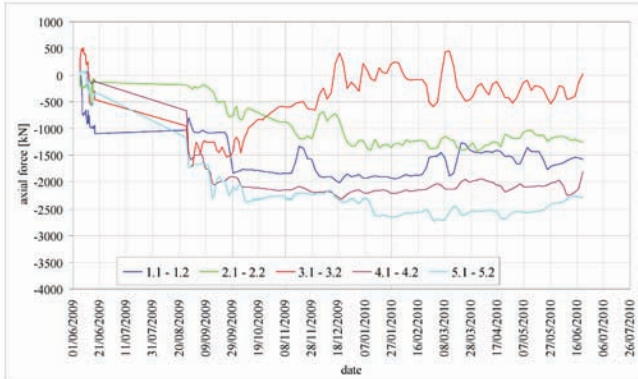

Figure 3b. Tunnel lining – Computed axial force vs time.

Table 1. Ring beam - computed axial forces						
Ring	**N1 [kN]**	N2 [kN]	N3 [kN]	N4 [kN]	N5 [kN]	N5/N1 [-]
III	**1415**	1600	2425	2740	3950	2.8

Table 2. Tunnel lining - computed axial forces						
Sez..	**N1 [kN]**	N2 [kN]	N3 [kN]	N4 [kN]	N5 [kN]	N5/N1 [-]
1.1-1.2	**1650**	1985	3290	3645	3645	2.2
2.1-2.2	**1240**	1580	2170	2585	2585	2.1
3.1-3.2	**190**	515	580	1095	1095	5.7
4.1-4.2	**2100**	2440	3830	4155	4155	2.0
5.1-5.2	**2530**	2865	4634	4925	4925	2.0

procedure which disregards all the effects previously listed can lead to significant overestimation of stresses.

References

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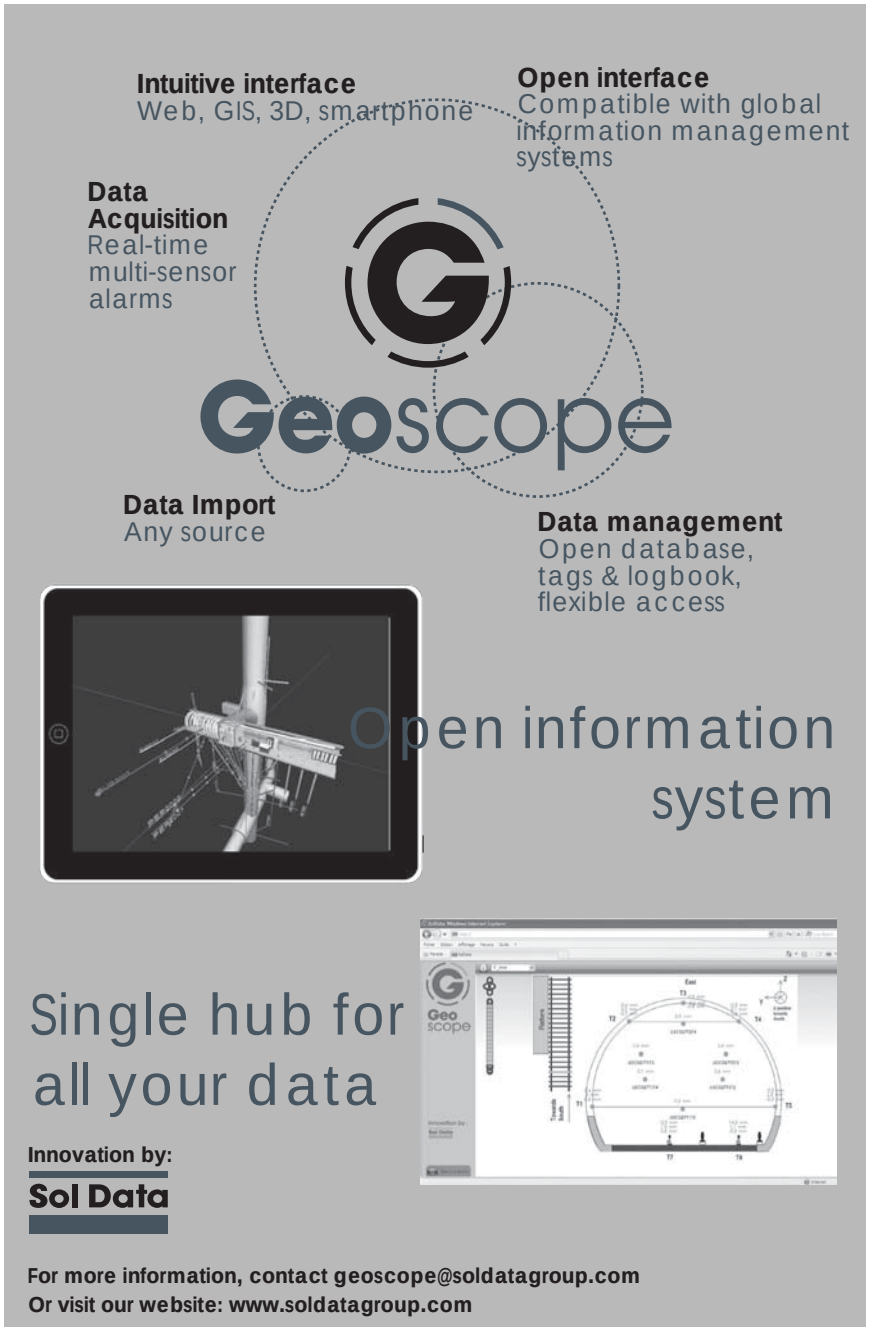

The Web Dissemination of Monitoring Data

Roger Chandler, Keynetix Ltd.

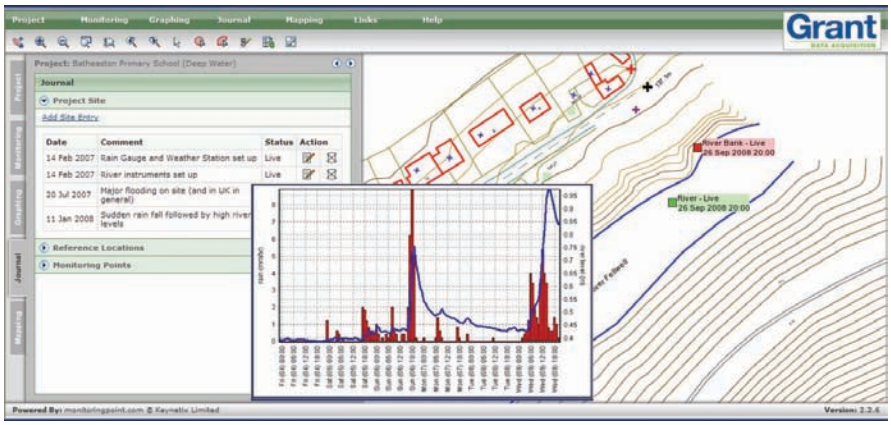

Figure 1. Branded Monitoringpoint.com for Grants showing results from major flood in July 2007.

More monitoring data is being collected electronically than ever before. As a result, a wide range of online and desktop software applications are being provided by instrument manufacturers to help you share data with your clients. Using the manufacturer's system can appear the easiest option but more often than not it's not the best option. This is especially true if you are working for a client who has multiple monitoring contracts.

Your client will have a learning curve before he can effectively use the system you provide. Even if you feel this time is short you must take into account that the client will be using it less than you and will often have long periods between uses and forget how to use certain features. If they have multiple contracts using different systems then this problem is magnified and can result in the client not wanting to use the system simply because they can never remember how to.

The best option for the clients is therefore to have every company working for them to upload their data into the same system. Selecting a system from a certain instrumentation manufacturer can however restrict competition for the monitoring contracts themselves. This is too high a price to pay for a standardisation of web based data; however selecting an independent system can give them these advantages without the restrictions.

This is the reason why Keynetix, a software company well know for it's geotechnical data management system HoleBASE, developed www.monitoringpoint.com in 2002 and why it has proved popular with clients and monitoring contractors. The system uses open data transfer standards from the AGS (Association of Geotechnical and Geoenvironmental specialists) to ensure that it is not tied to any proprietary format. To ensure that data can be created in this format Keynetix supplies software to convert most instrument manufacturer's formats into AGS.

Over the last 15 years I have worked a lot with the specification of UK and US data transfer formats for geotechnical monitoring data, starting with the UK and Hong Kong based AGS 2 format in 1994 all the way to the most recent version of AGS 4 and DIGGS.

If you are working in the UK on a large construction project you will probably be required to produce your monitoring data as AGS data as clients in the UK have had large exposure to this format and understand the benefits of not being tied to any one provider. In other countries this method of data supply is now also starting to see significant take up.

www.monitoringpoint.com offers customers the opportunity to have a portal to the system installed using their own web address and branded with the client's or company's information, thus making it look like a system developed for a project or a company at a small fraction of the cost of writing your own system. It is for this reason that instrument manufacturers such as Grant are now offering a rebranded version of www.monitoringpoint.com to their clients (www.squirrelview.net).

The system is a hosted service that allows projects to be accessed through the www.monitoringpoint.com address or via the client specific branded portal. The system can therefore be operational for a new client or instrument manufacturer within a day with a cost of less than a technician on site for a day. www.monitoringpoint.com is quickly becoming a popular route to market that not only benefits the manufacturers but also allows the clients to have all their data hosted on a single system.

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INSITE Web Based Data Management Software

Angus Maxwell, Maxwell Geosystems Ltd

Maxwell Geosystems have promoted the wider use of Observational Engineering within construction. Our INSITE systems have enabled projects to shorten the processing time from a few hours down to a few minutes and have encouraged engineers to specify more instrumentation and to rely on the results to give feedback on design. This has enabled them to refine designs and to rely on what the constructions are telling them rather than solely of the factor of safety assumed. These methods have improved safety on site and have lead to real savings in time and money.

Speed and Flexibility

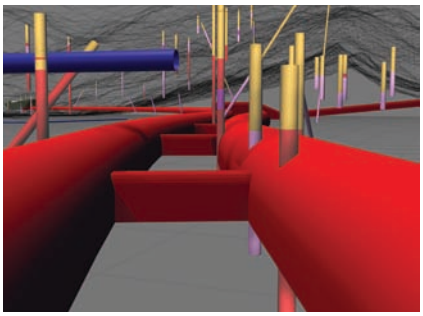

Figure 1. Construction and instrument data in one environment.

INSITE is designed as a dual layer system to optimize web speed. Raw data is held on local servers and is processed on the fly. Processed data is held on the web in simplified forms to enable superfast download and display. This redundancy means the web data can be recreated at any time. Local INSITE SERVER systems pull data from a variety of sources and check the data for integrity and credibility. Local administrators can use built in procedures to audit the data and quarantine any that may require further review. All changes to the data are time and user stamped. Back ups are automatic and in some situations continuous archiving is required where data volumes are large. The current record for one project is 25 million records.

Over 30 instrument types are currently supported and new types are added as required. INSITE can be customized to read structured data from any source visible to the program on local or wide area networks. This means that if you have a format that you like and it is consistent INSITE can be customized to read it. INSITE has over 70 pre-defined file based data input formats. All major data logger types are supported including most ADMS and vibration systems.

Observational Engineering

Instrumentation data is of limited use if the causes of movement are not clear. INSITE integrates setting out details for construction elements and tracks their progress along with other parameters Figure 1. These may be manually entered or drawn from construction logger such as tunnel boring machines. With our optional INSITE TDMS a full suite of construction progress and programme data is fully integrated into the software.

All data is displayed in our own custom GIS environment in both map (XY) and sectional (Chainage, level) views. All views allow full dynamic zooming and easy addition of new layers. The data can also be displayed in Google Earth and displayed as 3D views (contours surfaces) and even animated.

To aid the preparation of reports we have included binders both on the local side and web side to enable automatic production of reports to Excel and PDF.

INSITE Servers send alarms as emails and SMS messages. These are handled by our portal AAA blog which tracks responses. All our web portals are accessible by smart phones to enable responses to alarms to be made on the fly.

Powerful Analysis Options

INSITE is the first monitoring package to offer a dynamic alarm facility in which alarms can be linked to progress, proximity and prediction. This scheme enables actions to be taken ahead of time so that rather than requiring movements to be reversed they can be slowed to bring the construction back into the target zone. INSITE also includes the facility to group instruments into combinations so that a secondary parameter can be defined.

Tested on the Largest Projects

INSITE has been used in Hong Kong, Australia and Singapore. Projects have included embankments on soft clay, deep excavations, soft rock NATM tunnels and on a variety of TBM and Drill and Blast tunnels. INSITE is currently monitoring SE Asia's two largest projects: the Express Rail Link in Hong Kong (HK$67 billion) and the Airport Link in Brisbane (A$5.6 billion).

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asm@maxwellgeosystems.com,

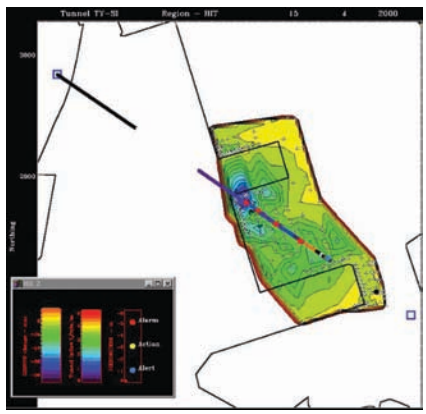

Figure 2. Animation helps bring out relationships in data.

MultiLogger Suite Web-based Data Management

Alex Neuwirt, Canary Systems, Inc.

MultiLogger Software

We've been hard at work for over 13 years now to develop software tools to help our customers in the Geotechnical Engineering discipline manage their collection systems and data. Our software can be described as a "hybrid" system, it consists of Windows® based workstation tools for automatically collecting data, populating a SQL database, configuring the project interface including notifications and outputs, and a web component for viewing the project including alarm status, creating any of the numerous outputs or data presentations, and entering data from the field.

Data Import

Data can be imported automatically or manually from virtually any source, either through the built-in automation (which includes automated program generation) for Campbell Scientific controllers, use of "import folders" for data from other data collectors or manual data entry. Data are validated based on tolerance criteria, this helps avoid alarms based on incorrectly collected or entered data.

Alarms

Four basic types of alarms are supported, calculations to include one or more data or calculated elements can also be configured with alarms for virtually unlimited alarm configuration. For example, the calculation engine includes aggregate and historical functions to reduce data and alarm based on time periods or other criteria.

Notifications

Five types of notifications are supported, alarms being just one type. Other notifications include scheduling electronic delivery of outputs, when new data are available, when specific data elements miss their update interval and when a specific group of data elements miss their update interval.

Outputs

Eight types of data outputs for data or calculations are supported including; Quick Report (columnar reports), Quick Chart (time series charting), Spreadsheet (Excel® worksheets), Instrument Report (statistical reporting), Element Chart (series of multiple elements, e.g. in-place inclinometer), Wind Rose (wind speed and direction), Event Chart (event data captures, e.g. seismic data) and Inclinometer (standard inclinometer surveys). Each output can be extensively configured.

Integrated Web Interface

All of these features are integrated into an intuitive password-protected user interface built on the idea of graphic views of your project and interactive icon placement based on location of instruments. Documents can even be saved into the database and associated with instrument icons to provide for storing information such as calibrations, installation photos or other reference materials associated with the instrumentation. This interface has proven to be an efficient and easy-to-use interface for experts and novices alike.

Summary

We've worked hard to integrate all aspects of geotechnical data collection (whether automated or manual systems) and management into a single, easy-to-use, yet powerful software system with Web interface. This allows personnel responsible for data management and reporting of their projects to focus their time and energy on the information that the instrumentation is intended to provide, not on managing the hardware and software systems. Ultimately this provides for maximizing the value of the instrumentation program and hopefully providing a safer and more meaningful work environment, and thanks to the Internet, one that is always close at hand!

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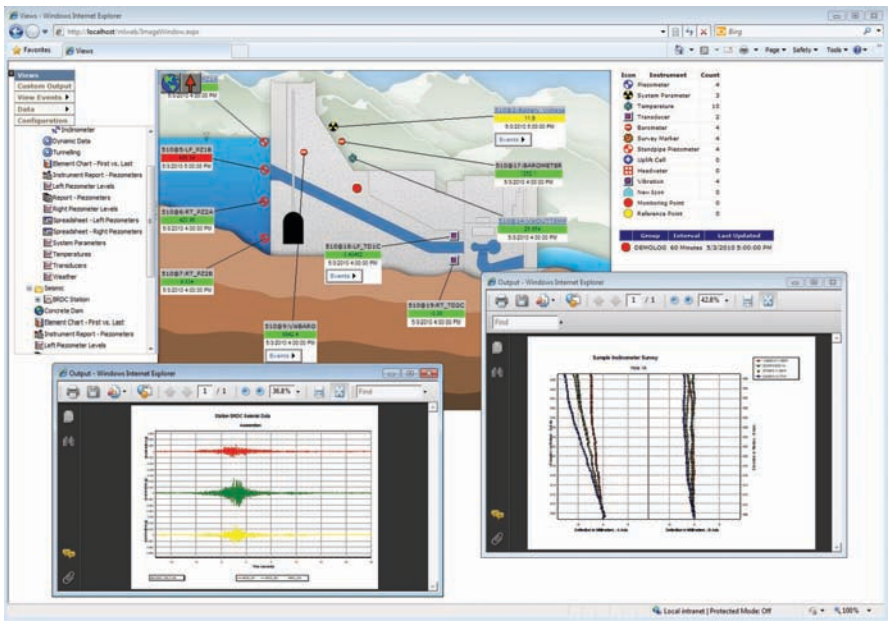

Figure 1. Sample project view with event and inclinometer outputs shown.

iSiteCentral Web-based Data Management Software

Rob Nyren, Allen Marr and Don Jacobs, Geocomp Corporation

Geocomp's *iSiteCentral™* service shown in Figure 1 has been operational since 1998 and provides integrated data collection, reporting and alerting capabilities for a wide variety of sensor inputs, data loggers and applications. The system provides a single data delivery interface for traditional data loggers, robotic total stations, seismographs, cameras and many other non-standard data feeds/sources.

Operations: The *iSiteCentral™* software and hardware reside in Geocomp's offices in Massachusetts. These systems operate continuously to monitor data from sensors all over the world. The data are stored into a secure Microsoft SQL database. Some features include:

- Automatic backups of the database every 30 minutes
- Automatic rollover to second server if primary server fails
- Separate modules for data exchange and data storage to protect integrity of the database
- SQL database structure enables to poll the data from outside the iSiteCentral system
- Extended data records permits storage of information about quality of each data point
- Device pollers handle data upload from most commonly used data loggers; website facilities to enter data manually and via direct spreadsheet upload.

A client version of *iSiteCentral™* is also available for installation at a client's facility. Configuration is based on client's specific needs for redundancy, mirroring and backup.

User Interface and Reporting Tools

All interactions between the customer and *iSiteCentral™* are through password-controlled WEB browser interface that allows clients and users to view and report data whenever he/she desires. *iSiteCentral™* contains reporting elements that permit users to create charts, graphs and tables to meet a specific project needs and requirements. Graphical forms include time history, x-y and multiple y axes. Links to plots, tables and sub-plans can be placed onto images at the website to show users both their location and current readings. The instrument symbols can be color coded to indicate sensors in an alarm state.

Interpretation aids: The *iSiteCentral™* system utilizes the concept of virtual sensors to allow advanced numerical manipulation of measured data. A virtual sensor is built using the data from one or more sensors and mathematical equations that relate the measured data to the quantity desired. Examples range from simple pressure transducer corrections for atmospheric pressures or tilt from deformation monitoring points (see Figure 1) to more complex calculations of bending strain from multiple gages, to linear and non-linear trend calculations that may be used for evaluating rates of change and for predicting future values. A scripting language is used inside *iSiteCentral™* via the website to set up these virtual sensor calculations. This capability also allows users to create complex alerts based on multiple sensor inputs to give automated early warnings and to perform cross-evaluation of data sources in real-time.

Alerting services: The Alarm Service option of *iSiteCentral™* monitors all readings to determine if a sensor reading has exceeded a present alarm value. Each sensor can have multiple alarm levels up to 15. Each alarm level can be programmed to cause *iSiteCentral™* to take specific notification actions. These include sending emails, text messages and synthesized voice messages to "call lists". An alarm acknowledgement feature allows a user to acknowledge receipt and deactivate an alarm via the WEB.

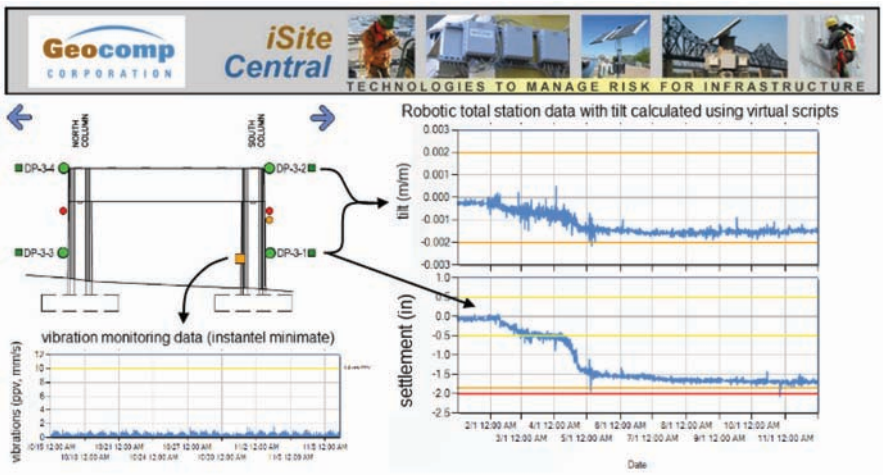

Figure 1.

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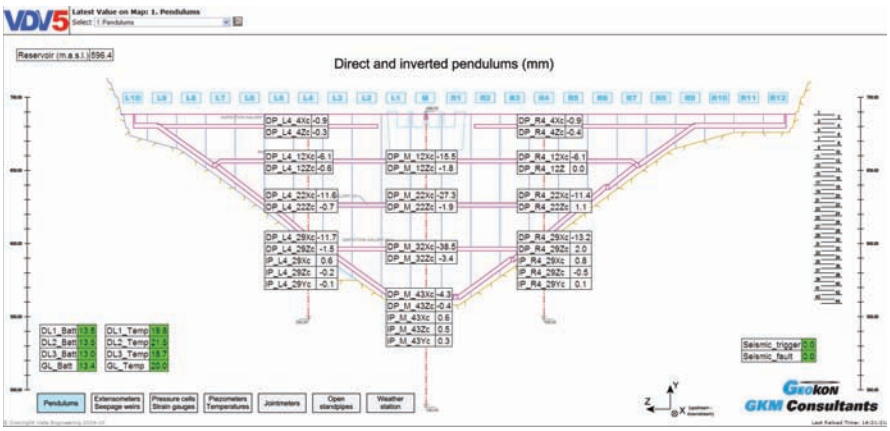
Web-based Data Management Software

Andres Thorarinsson, Vista Data Vision (VDV)



VDV is a comprehensive data handling software for geotechnical projects of any size. Includes data visualization, alarming, real-time displaying, reporting and web access to all data. Run VDV on your own PC for Internal Data Service, and as a Web Service for your staff and clients. VDV has been developed and used since 1991. New VDV version 2011 in Q2.

Data loggers supported: Campbell's Scientific Data Loggers, Geokon's Data Loggers (both via LoggerNet or MultiLogger), other data logger via VDV's File Converter and vendor's Call Engine. Supports Total Stations. Largest system known: 250 data loggers and 5k tags. Response time: 1-2 second average response time to PC Query or Web Query.

Data Interface: Display data as Time series, Displacement graphs, Rate-of-Change, XY-Graphs, Intensity Plots, Histogram, Data Table, "Wind" Rose for any data. Combine data from several locations into single overview. Easy-to-use interface, choose pen colors, thickness, background color, auto and manual Y-scales, linear or log time axis.

Data Handling: Built-in fully licensed MySQL data base capable of storing years of data from hundreds of projects. Alarms in 4 levels with sound/color/email. Validation. Virtual Variables for calculated results. Export of data for Excel. Run your own SQL queries. Reports with tables and graphs. Very fast response time unaffected by size of Data Base.

Web Service: VDV is ready to run Web Service right out of the box, no programming, only needs fixed IP number from a Service Provider. Use VDV as SCADA monitoring and/or as a research tool. Customize web layout. Navigate all graphs. Acknowledge Alarms. Write Notes about sensors and locations. Add Web Cams and Photos to any Project. Manual Input of data. Modify data. Support to Smart phones. Choose language of web service.

Real-time Handling: See latest data on maps in layers with navigation buttons and any picture or artwork as background. Display data as number, cluster of numbers or graphs. Show alarm status by background color. Support Google maps. Easy-to-use interface.

Download fully working version of VDV or participate in web-seminar to learn more.

References: Seattle Department of Transportation, USA; Tsankov Kamak Dam, Bulgaria; Linha 4 Metro, Brazil; US Army Corps of Engineers, USA, Ingula Pump Station/Dam project, South Africa; Desert Research Institute, USA.

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ARGUS Web-based Data Management Software

Hai-Tien Yu, ITM-Soil

Product Overview

ARGUS is named after 'Argus Panoptes' a giant in Greek mythology. He was famous in legend for having 100 eyes that made him a perfect watchman. ARGUS was originally developed in 2004 by Interfels in Germany, becoming an ITM-Soil product when ITM-Soil acquired Interfels in 2007.

ARGUS has been developed for the open-source LAMP system (Linux, Apache, MySQL & PHP). It is 100% web-based software. Users interact with ARGUS using industry standard web-browsers, there is no need to install any software or plug-ins on their PC. Working with ARGUS is platform-independent and can be accomplished in a local network or over the Internet from any location in the world. Multiple users can access the system simultaneously. There is no license to pay for each user.

Since its introduction, ARGUS has been used in many small as well as major projects around the world with a well proven track record including a number of underground projects including the Crossrail project in London and several Subway projects in New York.

ARGUS is under constant development to satisfy new user requirements including GIS (Geographical Information System) functionalities, construction progress information management and is compliant to AGS (The Association of Geotechnical and Geoenvironmental Specialists) data format.

ARGUS Features

In addition to all the standard functions of a web-based instrumentation data management system, such as storage, calculations, graphical presentation (Figure 1), alarm messaging, and reporting, ARGUS also has some unique features as follows:

- Users have the option to purchase ARGUS to run on their own server, or rent web spaces on ITM-Soil secured and fault-tolerant servers.
- Support for multiple languages currently including Dutch, German, English, French, Chinese, Spanish, Swedish and Finnish. Additional new languages can be added as required.
- User definable formula with references to any sensor in the project.
- Support for dual Y-axis allowing you to present two different engineering units in one plot
- Watchdog function to generate an email alarm if "no data received since x minutes'
- 'Virtual sensors' can be created to calculate specific values such as averages, absolute or relative measurements, corrected and uncorrected data etc.
- Automatic generation of PDF reports and distribution via e-mail. Reports can be customized by the user to include sensor plots, sensor values, alarms and other relevant information.
- Built-in functions allowing users to create backups & archives from data and configuration settings in the database to the user's PC.
- Built-in FileManager and LogBook functions for user to input additional project information.
- The latest version incorporates GIS functionalities (Fig 2), TBM (tunnel boring machine) data, multimedia records (videos and photographs) and permission group management.

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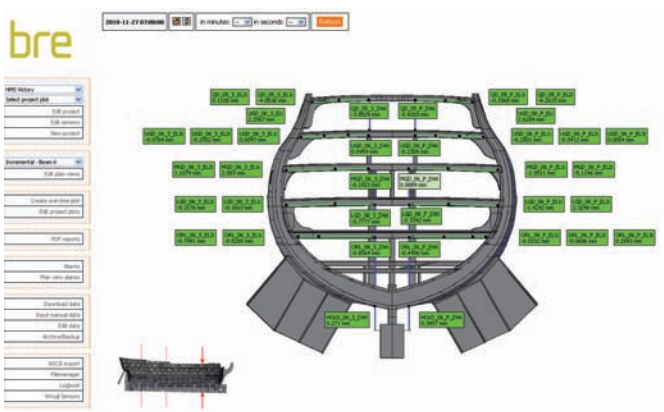

Figure 1. Typical ARGUS project view.

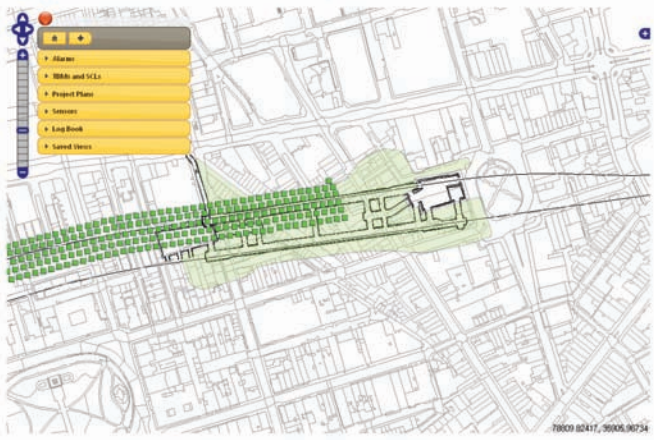

Figure 2. ARGUS with GIS interface.

GeoViewer™ Web-based Data Management Software

Rob Taylor, RST Instruments Ltd

Introduction

GeoViewer is a data viewer originally developed in 2000 to provide flexible console viewing of large data sets from ADAS (automatic data acquisition systems). The program runs on Windows™ .

Data Source

Much GeoViewer data originates in data loggers which transmit their data by various logger-specific means to files which are locally or remotely accessible to the GeoViewer server. Because of this file model, any file with a public format which contains time-stamped data may be presented in GeoViewer: spreadsheets, databases, comma-separated text files, GPS and total station data, public weather data etc.

Data Storage

RST suggests that all stored data be as raw as possible, e.g. vibrating wire sensors should be stored in "B units", and that data from multiple sources should be kept separately in original, maximally readable format. In the case of logger data which is constantly appended to a file this is by far the simplest and most reliable approach. Standard file server backup strategies are used.

Historically, such an approach might have strained the resources of available computers, but as time passes, the power of reasonably-priced servers has increased to the point that a server with 200 loggers communicating by dozens of paths, 6,000 sensors, years of hourly data, and dozens of simultaneous web access users gives excellent performance. At the same time, all data is in a format that can be checked against manual readout data and sample calibrated with text file and spreadsheet tools.

Calibration and Computation

With all data storage in raw format, calibration is typically performed on-the-fly using a calibration database. Numerous functions are available: linear, polynomial, transcendental, relational across the entire system (not just within a logger).

Deferred calibration is a powerful maintenance tool: if the calibration of a sensor is found to be incorrect, the appropriate calibration page is edited, and the entire record is automatically updated from the first reading.

Data Presentation

Data presentation is typically as views which are designed for efficient use. They may be:

- mimic views with stoplight (green/yellow/red/blue/grey for ok/warning/alarm/alarm-off/stale data) buttons which "drill down" into other views
- lists with stoplight coloured numeric fields
- time series plots with one or more channels with alarm levels, different sampling rates
- exaggerated profiles for inclinometers, tilt beam etc
- linked files: installation photos, logger programs, calibrations, notes, all one mouse click away from the data

Alarm Functions

Full featured alarms are available for all channels, calculations from channels, communication status etc. The alarms include high/low warn and alarm levels, hysteresis, event triggers, alarm levels computed from data, device outputs, privilege alarm mask. It is suggested that not every channel be alarmed and alarms be implemented incrementally to minimize nuisance alarms.

Data Archive

With the low cost of data storage, archiving may be at job end only, even for the largest construction projects. For permanent installations where data goes on indefinitely, relocating (but retaining) older data may be useful to keep records manageable. Resampling older data may be used to decimate the size of on-line records, e.g. weekly min/max instead of hourly data divides quantity by 84, but permits historical context to be on-screen.

Web Functionality

GeoViewer utilizes Internet communications in numerous ways. Data acquisition may use wired or wireless web communication as a link in a communications chain, local and wide area networks may be used to access data files outside the GeoViewer server, back-up may use offsite resources.

End users may view data securely by remote computer or mobile device, and receive alarms by e-mail, text messages etc. Privileged users can maintain the system from offsite, typically by VPN (virtual private network) remote access. Because of the limited screen size of mobile devices, mobile-friendly views are typically required, with large buttons and reduced clutter.

Business Model

GeoViewer is typically sold as a purchase/annual maintenance product; i.e. the customer owns the product and runs it on his or her server. The purchase cost is based on number of servers running (typically one), and the number of simultaneous advanced viewers. On-and off-site training and assistance are available.

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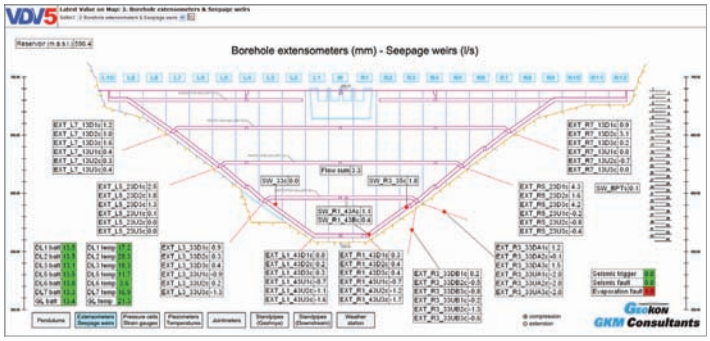

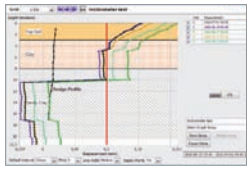

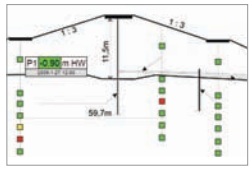

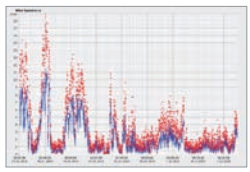

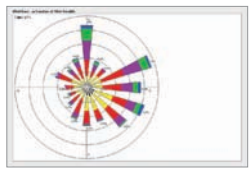

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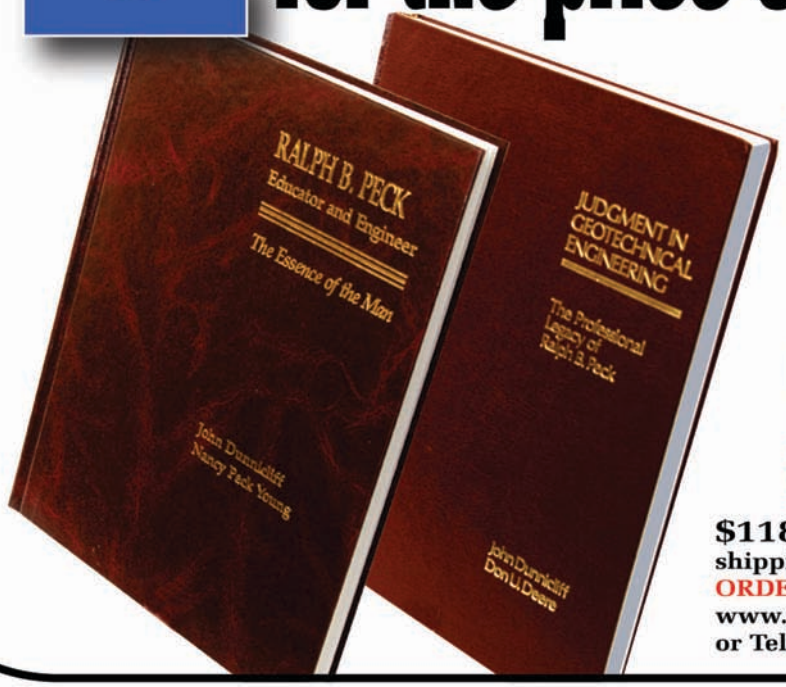

1. Ralph B. Peck Educator & Engineer-The Essence of the Man by John Dunnicliff and Nancy Peck Young

2. Judgment in Geotechnical Engineering - The Professional Legacy of Ralph B. Peck by John Dunnicliff and Don U. Deere.

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