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Geotechnical instrumentation data management

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ABSTRACT: In response to the need for effective and timely management of information and monitoring data, this paper introduces two complimentary applications that have been developed for tunneling projects to manage geotechnical information. They have been successfully used on a tunneling project in Italy and are now being used on two major tunneling projects in Canada as well as other smaller projects.

A Geo-Engineering Content Management System (GECMS) has been developed. A one-stop web portal designed to aid project designers, construction and monitoring crews to manage all geo-engineering and related documentation, instrument monitoring data and spatial data both historically or generated during a project.

Monitoring is a key part of any excavation and one of the major concerns is timely management of the instrumentation data to verify design parameters as development proceeds. As technology is ever changing, data is collected automatically and more frequently, new techniques are needed to manage the data, this is where the Geotechnical Instrumentation Data Interpretation and Evaluation (GIDIE) application has been implemented.

1 INTRODUCTION

Effective and timely management of information and monitoring data is a key part of any geotechnical excavation project. As technology is ever changing and now that data is collected automatically and more frequently, new techniques are needed to manage the volume of data generated. Recognizing these needs Golder has developed tools to make this possible through a content management system (GECMS—Geo Engineering Content Management System) and Instrumentation Data Management and Monitoring application (GIDIE—Geotechnical Instrumentation Date Interpretation and Evaluation). Both of these applications are web based and available to those who have security rights; they complement each other and can be implemented either together or independently. GIDIE has been successfully implemented on a recently completed tunneling project in Italy, and through experience with this project both applications have been upgraded to be more efficient.

The collection and management of monitoring data has changed significantly over the years, the author has been working with instrumentation and monitoring programs for over 35 years and through this experience has lead the development of these applications.

2 THE NEED FOR DATA MANAGEMENT

The experience of 35 years of collecting and analyzing geotechnical data, where through the years data has been collected manually by collecting and plotting by hand on graph paper; to automated collection and plotting using handheld devices; to spreadsheets; and now to databases and web delivery show how technological changes can help in analyzing data in a timely manner (Gilby, Yuen & Aston, 1988). Through each of these stages, the volume of data has increased and the need to manage it more effectively and efficiently has become more evident.

As technology changes have allowed for more data to be collected, management has become more difficult and although computer speeds have increased significantly the large volumes of data collected have meant that the analysis does not necessarily become any easier (Borgonovo et al., 2007).

The data management techniques described in this paper were devised from experience and the application has been developed with the following needs:

- A flexible efficient database for holding data through user configuration;
- Access to data from anywhere there is an internet connection to allows for interrogation of

readings in the event of alarms and to allow viewing by users with rights to the data;
– Ease of use and quick access to tools, graphs and reports;
– Flexibility to evaluate, accept and reject data based on prescribed conditions;
– Consistent and flexible reporting tools including text and charting, including personalized needs; and
– Import and export of data to allow for further processing.

3 CONTENT MANAGEMENT (GECMS)

3.1 *Features*

The Geo Engineering Content Management System (GECMS) Web Portal provides the user with single sign-on to multiple components tightly integrated together:

– A powerful Document Management System that enables the user to upload and share all the project related documents, and to publish the documents for authorized use through a robust revision and approval process.
– Multiple ways of searching for documents:
  • Spatial Map search: where the user identifies a location on the map and is provided with the list of documents the user has permissions to read, linked to the location selected. From this list, the user can click on a document and see it on-line in the browser.

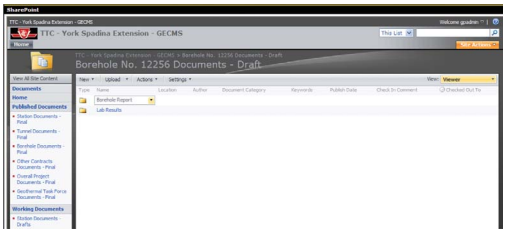

Figure 1. GECMS web portal.

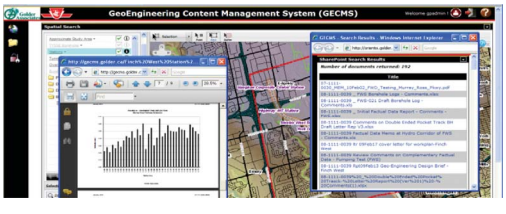

Figure 2. Saptial map search.

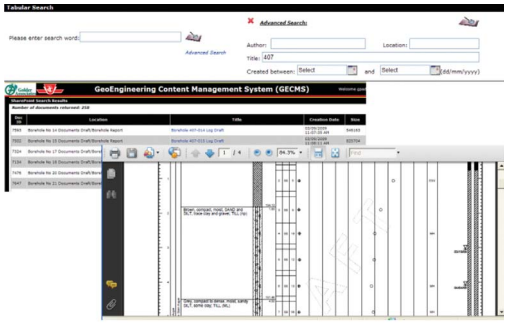

Figure 3. Tabular search.

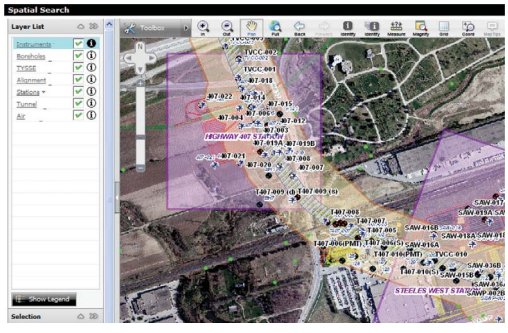

Figure 4. Spatial data viewer.

  • Tabular Search: when the user knows more details about a specific document he is searching for (i.e. part or full title, author, creation date, etc.), the user can enter the searching criteria in a form and is provided with the list of documents he has permissions to read, that match the searching. Again, just one more click and the desired document is displayed in the browser.
  • Spatial data viewer—GIS query, viewing and mapping tool displaying Geo-engineering spatial data such as boreholes, infrastructure and topographic data, and also all the monitoring instruments.
  • Instrumentation Data Management and Monitoring tool (GIDIE).

3.2 *GECMS document workflows*

There are two main document workflows in GECMS: Document Publishing and Document searching.

– GECMS enables various document management roles contributing to document workflows within GECMS. GECMS Administrator—administers the site.

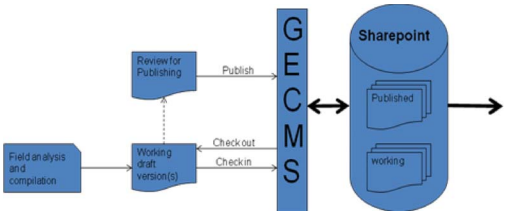

Figure 5. GECMS document workflow.

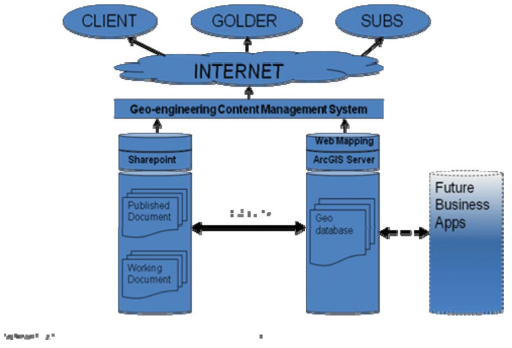

Figure 6. GECMS workflow.

- Publisher—publishes draft documents into published documents.
- Contributor—creates, loads and edits documents in working draft folders.
- Viewer—view only of published documents.

In some projects spatial data is updated on a regular basis and would go through a similar publishing process.

3.3 *Benefits of GECMS on large geotechnical projects*

There are many benefits to implementing a content management system especially on a large geotechnical project that combines a high volume of information with many disconnected users of the information. The major benefits that can be realized are:

- Project spatial data managed in one central location;
- Project documents managed in one central location;
- Enables limited and secure access to documents;
- Enables version control of documents;
- Links project documents to spatial locations to enable spatial searching;
- More than one document can be linked to one spatial feature;
- Collaborative document sharing and development; and
- Can integrate spatial and document management with other databases such as EquIS, gINT and acQuire.

4 INSTRUMENTATION DATA MANAGEMENT (GIDIE)

4.1 *Features*

Based on experience we developed a series of features to be included in the monitoring application. The key to the application is a robust and well thought out data model and much time has been spent on this. The database has been developed in SQL Server. The tables in the database are configured to allow input of the following:

- Project or section data;
- Administration and user information to allow for secure access;
- Instrumentation information;
- Device information (in this case the differentiation between instrument and device is for example that a 4 point extensometer would be an instrument and each anchor would be the device); and
- Formulae for calculation of reduced/engineering values.

Each of the above has sufficient fields to define the use completely as follows:

- Information to allow the database administrator to configure and administer the users and their permissions;
- Definition of the project and/or sections;
- Web Portal Application look-and-feel customization per project and/or section;
- Instrument details showing the devices within the instrument, its location, etc.;
- Serial numbers of devices;
- Calibration constants, which can change with time if re-calibration is necessary;
- The number of devices in the instrument;
- Formulae required to reduce the data from raw readings if necessary;
- Flags to show whether processing is required or not;
- Alert and alarm levels, and the action to be taken if there is an exceedence; and
- The type of report and chart required (whether 1 device per plot or multiple devices per plot). Most plots are time against some reading; however there are special needs for example inclinometers and plotting tunnel advance against readings.

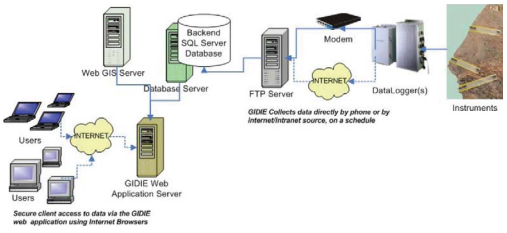

Figure 7. Integrated application of GIDIE.

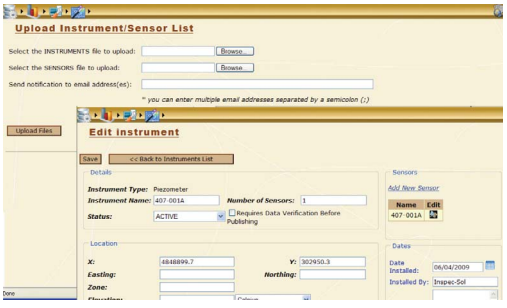

Figure 8. Instrument upload.

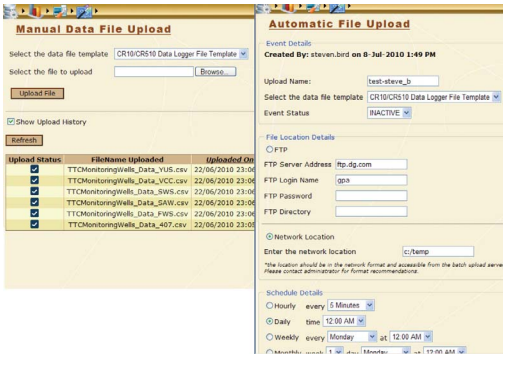

Figure 9. Manual data upload.

The flexibility of the system allows users with administration rights to define new instruments that may not be currently supported or even developed. In some cases it may however be necessary to add features to this to allow some new instruments to be included.

During the development of the application and in response to stakeholders, a number of instruments have been incorporated and as more are requested, the specifics of these instruments and sensors will be programmed into the application. Currently the application supports the following instruments and charting types:

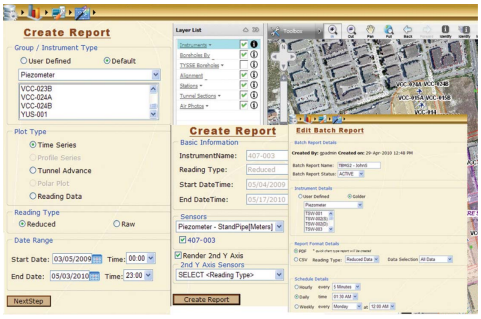

Figure 10. Reports.

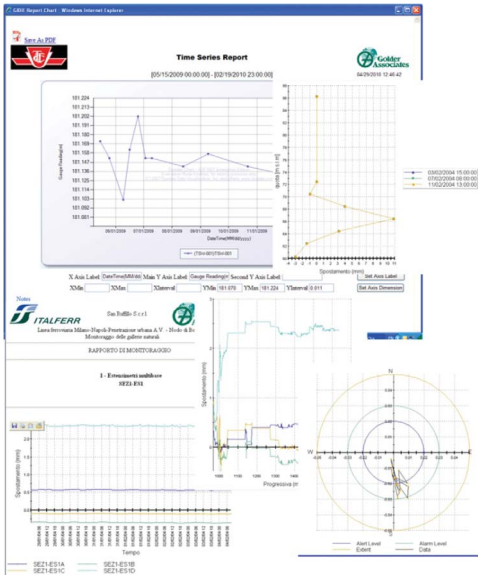

Figure 11. Custom graphing and reporting.

- Vibrating wire instruments (strain gauges, extensometers, piezometers, pressure cells, jointmeters, etc.);
- In place inclinometers (vw and servo acc.);
- Manual inclinometers;
- Electolevels;
- Topographical instruments;
- Hydraulic instruments (load cells, etc.); and
- TBM/tunnel/excavation/construction advance.
- User definable instruments and devices that have similar features to the supported ones (new devices may need additional programming before completely supported—ongoing support);
- Charting supports:
  - Single instrument (time v reading);
  - Multiple devices in one instrument (time v reading);

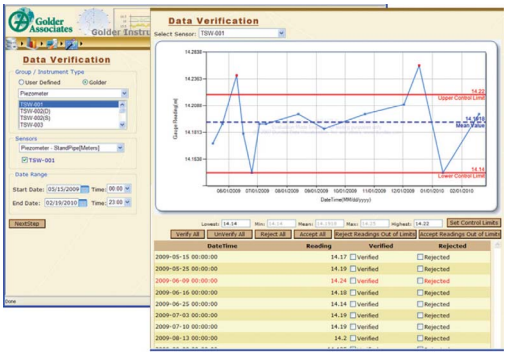

Figure 12. Data verification.

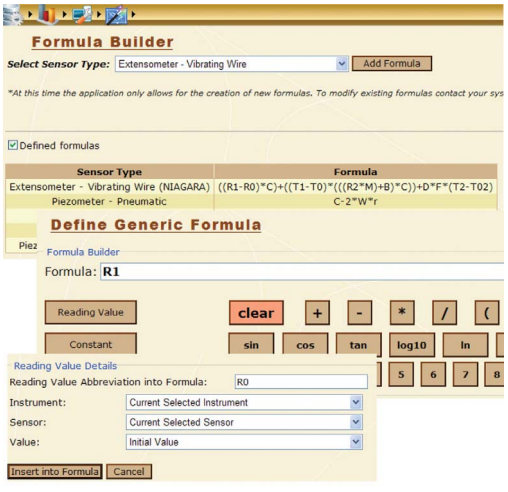

Figure 13. Formula builder.

- Inclinometer plots;
- Polar plots;
- Combination plots; and
- Tunnel-settlement plots (plotting instruments referenced to the tunnel location).

4.2 *Application*

GIDIE is a powerful Instrumentation Data Management and Monitoring tool that is tightly integrated as a module with the spatial and document management system components from the Web Portal but can also be used as its own application. The following shows a schematic example of how the data flows from the instrument to the users' computer via communication and the database.

Following are a series of screen shots of the application and its features:

- Instruments and Devices are easy to be defined in the system either manually or through automatic upload of a list of instruments/devices.
- Calibration information can be entered at any time an instrument needs to be calibrated; updated formulas would be applied automatically to calculate the corrected values.
- Data from instrumentation can be loaded automatically through various communications methods as well as manually in near real time and is available for immediate analysis.
- Quick Access to Flexible Reports and Graphs for one or multiple instruments—allows for creation of reports real-time or batch mode at predefined times (the reports can be sent by email to various stakeholders in .pdf or .csv format).
- Various graphical methods of presenting the data including batch printing of custom charts.
- Data export for usage and integration with other applications (export in .csv format).
- Data Verification—allow the user to visualize the data and reject the erroneous values.
- Formula builder to calculate reduced readings from raw data—automatically integrated in the data upload process.
- Multiple levels of security in accessing the instrumentation data:
  - Reader (who can only view reports for specific instruments)
  - Writer (who can upload data either manually or automatic; or verify the correctness data)
  - Power User (who can also enter new instruments/devices; change calibration details).

4.3 *Integration of GIDIE into GECMS*

When GECMS is used as a portal entry to GIDIE, tools providing interface, mapping and document management are managed through GECMS. The following GIDIE information items can be stored and managed in GECMS:

- Instrument locations
- Instrument specifications
- Instrument Calibrations
- Instrument installation report
- Monitoring reports (manual or scheduled).

5 CASE STUDY—TORONTO YORK SPADINA SUBWAY EXTENSION

5.1 *Background*

- 8.6 km long extension of the Spadina Subway line from Downsview to the City of Vaughan in York Region.

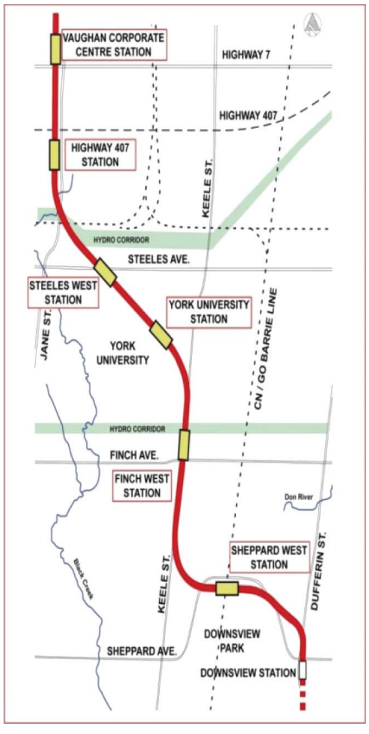

Figure 14. Toronto transit commission TYSSE project.

- First subway line crossing the City of Toronto boundaries
- Funded by three levels of government:
  - The Government of Canada
  - The Province of Ontario
  - The City of Toronto and The Regional Municipality of York
- Cost: $2.6 billion.

5.2 *The need for GECMS*

- One of the primary concerns was document management
- Documents to be stored at one location
- Documents to be easily sharable among stakeholders or contractors working at the same project location performing differing but dependent tasks
- Add spatial element to the document management.

5.3 *Golder's role*

- Golder has been retained by the TTC as the Principal Geo-engineering Engineering Consultant for the TYSSE project.
- Golder's primary role is management of subsurface risks and the development work including the following:
  - Oversight role on geo-engineering works;
  - Site investigation standards and minimum investigation requirements;
  - Review of the Geotechnical sections of the design manual;
  - An overall strategy for managing soil and groundwater; and
  - Review of the data obtained from the construction instrumentation program.
- One of Golder's key deliverables is to develop and maintain a Geo-engineering Content Management System (GECMS).
- GECMS is designed to manage all geo-engineering and related documentation and spatial data both historically or generated by this project.
- Golder has successfully integrated these web mapping, document management and instrumentation data components into a one-stop web portal to aid stakeholders, project designers and construction contractors.

6 BUSINESS CHALLENGES OF WEB DEVELOPMENT

As GECMS is a web deployed application, accessible from anywhere in the world by many user groups with differing business environments, many business challenges arise. The following are some of the business challenges and the mitigating measures taken to overcome each.

- Many sub contractor (multi-agency) teams managing a variety of inter-related geotechnical and geo-environmental tasks:
  - Management of document security—limited sharing of working drafts.
  - Manage document versioning workflow—from working draft to publish.
- Spatial data currency—constant updates:
  - Establishment of spatial data workflow ensuring timely and quality updates.
  - TTC base updates workflow.
  - Station and tunnel alignment updates workflow.
  - Borehole location updates workflow.
- A variety of internal office automation environments, internet connection speeds and browser versions:
  - Provision of additional training and support.
  - Test on many environments to ensure minimum functions.
- A variety levels of computer savvy amongst users:
  - Provision of well documented system.
  - User training.

- Train the trainer.
- Additional training for administration staff.
- Provision of additional support.

7 CONCLUSIONS

The GECMS/GIDIE application has been developed to automate and simplify data collection and interpretation from documentation and instrumentation systems. Over the years there have been a variety of methods of collecting and reducing such data that have been time consuming and once the interpretation has been made, the excavation has often past and the data is of less use. By incorporating this system into a near real-time web based application, data can be evaluated much quicker for contractors and designers to evaluate the safe working and to verify design parameters.

This application has been used on a number of monitoring programs with the major ones being tunnel development in Italy as well as current tunneling projects in Toronto and Ottawa, Canada.

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