Geotechnical Data Management: Construction Applications

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Outline

• Information Management System (IMS) and GIS Concepts
• Data Management Technologies
• Case Studies
• An Information Management System is about Completeness
  – Compile everything in one single authoritative data repository
    • Version control
    • Data Quality
  – Link historical and ongoing construction data
  – Provide insight by analyzing and visualizing data in context of all site information
The IMS Concept

- An Information Management System is about Efficiency
  - Timely reports and summaries (automated as-built)
  - Ease of data access and usability
The IMS Concept

• Allow contractors and owners tiered access to data:
  – Information is more easily digested when broken up into levels complexity from a broad overview down to the more detailed and complex
  – Tier 1: “Executive Summaries” on web or desktop GIS viewers
  – Tier 2: Detailed Reports in database and GIS work products
  – Tier 3: Raw data in database
Data Management Tenets

- Single Source Data – All information officially “lives” in a single place
- Untouched Data – Eliminate or minimize transcription
- Non-proprietary Data Formats – no data held hostage
- Spatial Consistency – Standard and consistent coordinate system
- Transferability – Easily “packaged” and documented
- Documentation – Every file, table, field, relationship and record
The Geospatial Information Management System (IMS) Concept

• Design, populate and maintain geospatially enabled enterprise databases for use in large-scale construction projects

• Include ALL project data:
  – Survey Data
  – Geology (regional, site-specific)
  – Historical borings (stratigraphy, water)
  – Maintenance records (settlement, repairs)
  – Laboratory test results (strength, index)
  – Field test results (CPT, load test, instrumentation)
  – Construction records (grout zones, anchors)
  – Project management (productivity, cost)
  – etc.…

• Provide near- or real-time data visualization from several data streams (e.g., project progress, instrumentation, manual measurements, etc.)

• Facilitate owner, consultant and contractor access to data:
  – “Executive Summaries” on web or desktop GIS viewers
  – “Detailed Access” in databases and GIS work products
Generalized IMS Workflow

Inputs
- Field Observations
- Instrumentation Dataloggers
- Documents
- Maps, CAD, existing data

Storage
- Enterprise Database
- Database Management System
- Document Library

Access & Outputs
- Website Dashboard
- GIS
- Reports & Drawings
Geographical Information Systems (GIS)

• GIS is a type of database with specialized fields and tools to handle spatial data
• GIS = Location + Attribute
• Concept is simple:
  – All points on the planet have a unique x-y (and sometimes z) signature
  – GIS allows us to track information and assign this information a unique values of x, y, and z
  – Attribute information allows filtering, joining tables, symbolizing
• Information is managed in a database and visualized on “layers” of a map
Geographical Information Systems (GIS)

- GIS Software (commercial or open source) can be used to:
  - CREATE spatial features (create shapes/geometries in designated positions, assign attributes; stored in local files or spatial server databases)

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pile</td>
<td>Station</td>
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<tr>
<td>P102</td>
<td>01+02.0</td>
<td>14.4</td>
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P100, P101, P102
• GIS Software (commercial or open source) can be used to:
  - ANALYZE the features
    - Where do the piles overlap?
Information about the wall construction being displayed in several ways simultaneously.
• GIS Software (commercial or open source) can be used to:
  - **ANALYZE** the features
    • Where do the piles overlap?
    • How frequent are grout connections in fractured bedrock?
    • Are instrument spikes associated with nearby drilling?
    • View disparate data sources in a common context (geology vs. geohazards)
    • Interpolate boring data into geological units
    • Identify challenges for design and construction by statistical analysis of field and laboratory data
• Use GIS Software (commercial or open source) to:
  – **INTERACT** with data/features (desktop or web-based interactive maps)
    • Navigate the map (Pan and Zoom, recall spatial “bookmarks”)
    • Turn on/off different layers
    • Identify feature information in an attribute table
    • Open related documents and files (by directly clicking with a tool or via attribute hyperlinks)
Populating GIS – Grout Visualization

- Borehole Log Data
- Automated Grout Monitoring
- Grout Monitoring Metadata
gINT + Grout Data + Database + GIS
gINT + Grout Data + Database + GIS

Map Layers

Layer Theme: All Available Layers (default)

- Grouting
  - Ground Surface
  - Top of Rock Surface
  - Total Grout Injected
    - Total Grout Injected (gal) (Upstream)
      - Total Grout Injected (gal) - Primary
        - ≤10
        - >10 - 50
        - >50 - 100
        - >100 - 500
        - >500
      - Total Grout Injected (gal) - Secondary
      - Total Grout Injected (gal) - Tertiary
      - Total Grout Injected (gal) - Quaternary
      - Total Grout Injected (gal) - Quintinary
  - Total Grout Injected (gal) (Downstream)
- Water Testing
Case Studies

• **Crossrail:** Performance monitoring for large linear transportation system

• **Bolivar Dam:** Interactions of geoenvironmental and geologic data for large infrastructure
Case Study: Crossrail’s Underground Construction Information Management System (UCIMS)

Source: Crossrail

engineers | scientists | innovators
Crossrail is one of Europe's biggest construction project with projected costs of $25.5 billion.

Expands the London Underground with shafts, tunnels, and portals that extend beneath the already congested system.

UCIMS developed with itmsoil for performance monitoring of a host of construction activities.

UCIMS also tracks the progress and performance of Tunnel Boring Machines (TBMs).

Geosyntec developed an intuitive, map-based user interface for the UCIMS, showing progress and data locations relative to surface features and other information.
UCIMS: Scale

- Web-based delivery, rather than desktop software
- Clustering algorithms used to group sensors, allowing thousands of sensors
- GIS Server used to provide data at different zoom levels.
- Sensor Filtering interface to quickly narrow down the number of sensors:
  - Sensor Name
  - Sensor Group – Area A, Area B, etc.
  - Sensor Type – Electrolevel, Tiltmeter, Crackmeter, etc.
  - Spatial – i.e. distance
  - Alarm Types – Red, Yellow, Green
  - Ability to save and Load Filters
UCIMS: Scale
UCIMS: Context
UCIMS: Context

• TBM Position provides context to sensor readings
  – E.g.: Alarm goes off – is it because of recent work?

• Incorporating building information and other GIS data layers, such as station numbering add access to relevant information
  – E.g.: How does the current settlement compare to the predicted settlement?

• Context can come at a price – complexity, so a limited number of grouped base layers (above ground, below ground, project map, etc.) simplify the user experience
Case Study: Bolivar Dam, Bolivar, OH

Source: Crossrail
The Project

- Bolivar Dam – Big Sandy Creek of Tuscarawas River, in Bolivar, OH
- Owned by USACE Huntington District
- USACE identified need for barrier wall to address seepage that is “negatively affecting the structural stability of the dam resulting in increased risks to the downstream public”
- Treviicos South (TIS) contracted to install
  - the seepage barrier wall, approx. 600,000 sf by panel method
  - the grout curtain (subcontracted to Terrafirm)
- Construction began January 2015, projected completion June 2016
Project Specifications Construction and Data Management

• Seepage Barrier Wall Construction Performance Requirements
  – 4,800 ft. length, 144 ft. maximum depth, 24 in minimum thickness, 6 in minimum overlap (confirmed with Koden)
  – Panels 0.25% Maximum deviation from vertical
  – Seepage Barrier Material 1e-6 cm/s maximum permeability, 750 psi unconfined compression strength

• Data Management Specifications
  – Secure FTP site used for submittals and data transfer
  – Database accessible “live” to USACE
  – Website with data input and reporting tools
  – Online and Offline Mapping tools
  – gINT Database
  – Data Management Plan
Roles and Responsibilities

• The OWNER (USACE)…
  – Needs to know that a Barrier Wall was built to their Specifications
  – Needs to know they can access the data produced by the Contractor quickly, transparently, and in a format that facilitates understanding
  – Needs a product that uses non-proprietary software that will be maintained long after construction completion
  – Needs a tool that will visualize the data to facilitate confirmation of a successful design

• The CONTRACTOR (TIS)…
  – Needs to know that the data they produce prove that the Barrier Wall meets the Specifications.
  – Needs tools to quickly and efficiently submit their data and interpret their data such that they can correct construction where necessary. **Submittal of these data is on the critical path to backfilling of the seepage barrier panels**
Verticality Import and Analysis
Web-Based GIS: Plan View
Project Website

- Document sharing and storage
- Host Web reports and Web maps
- Allow data download for local use
- Collaboration tools
  - Calendars, notes, documents
Project Website

Plan Viewer - Internet Explorer

Plan Viewer - Mobile

Grout Submittal Tracking

Profile Viewer - Internet Explorer

Profile Viewer - Mobile

Enter As-Built Drilling and Grout Hole Data

engineers | scientists | innovators
Data collection and transfer tools

- Online data entry spreadsheets
- Field form applications (off-line access)
- sFTP site (secure File Transfer Protocol)
  - Easy to script automated file transfer
  - “Synced” folders from field to office computers
Data collection and transfer tools

This append tool will upload Koden "txt" files and Hydromill "xls" files to the BDIMS Database from a directory supplied by the user and save those files in a second directory supplied by the user.

**STEP 1: Populate the Panel Log with Relevant Data**

A backup will be placed in the directory of this file. Backups if you need to retrieve information.

<table>
<thead>
<tr>
<th>Panel</th>
<th>Bore</th>
<th>Bore Station</th>
<th>P1/3 Left Ear</th>
<th>P1/3 Left No</th>
<th>P1/3 Left Sta</th>
<th>KodemSurvey_P1-3</th>
<th>P2/4 Right Ear</th>
<th>P2/4 Right No</th>
<th>P2/4 Right N</th>
<th>P2/4 Right E</th>
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</table>

**STEP 2: Input data for use in reports**

<table>
<thead>
<tr>
<th>Panel</th>
<th>Excavation Date</th>
<th>Pay Wall Elevation</th>
<th>Left Edge Easting</th>
<th>Left Edge Northing</th>
<th>Right Edge Easting</th>
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<td>559</td>
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</table>
Data collection and transfer tools – Form with QC

Click here (if permitted) to digitally approve excavation (name and date/time automatically "stamped")
• Relational Database built in web-accessible format
  – MS SQL Server, MySQL, Oracle, etc.
  – Relational Database = Tables + Relationships

• “Schema” = Description of tables and relationships
  – Definitions of each table and field (column)
  – “Rules” for each table
    • Primary and Foreign Keys
    • Field Types
    • Required Fields
Enterprise Database - Relationships

• [Borehole] table
  – 1 record per borehole
  – Stores location, top elevation, driller, drill methodology, etc.

  “1 to many” relationship with…

• [Geology] Table
  – 1 record per borehole/depth interval
  – Stores depth to each contact, observations in that depth range
Database Management System (DMS)

- The DMS contains the (documented) procedures (i.e., coded automated routines) that facilitate:
  - Data Import (validate and append records)
  - Data Export (query and serve data to reports, analyses, map sources etc.)
  - Data Management (usage statistics, author of data record, date of last update, etc.)
M & H-Line Water Pressure Testing
(Sta. 0+00 to 3+20)
• Need technologies to:
  – Compile automated and manual instrumentation data into a common database
  – Relate those data to instrument attributes (location, construction details, owner, materials, etc.)
  – Analyze data
• Data Analysis:
  – Are any values in exceedance of an ALERT/WARNING or ALARM level?
    • Report, communicate (e-mail, text message, alarm, etc.)
    • ...but is the alert an outlier or otherwise explained statistically?
  – Are any instruments TRENDING towards an alert?
    • Trend analysis...regression, or non-parametric analysis where possible
  – Are any instruments changing RELATIVE to each other?
    • Piezometric surface across dam
• Trend Analysis: is the water level in this piezometer decreasing?
• Outlier Analysis: is the alarm real?
• Relationship between instruments
Instrumentation Workflows
### Piezometer - Water Elevation Statistics

<table>
<thead>
<tr>
<th>Location</th>
<th>Min Today</th>
<th>Avg Today</th>
<th>Max Today</th>
<th>Min Yesterday</th>
<th>Avg Yesterday</th>
<th>Max Yesterday</th>
<th>Min Month</th>
<th>Avg Month</th>
<th>Max Month</th>
<th>Min Year</th>
<th>Avg Year</th>
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</tbody>
</table>
Wrap-up

• Put Everything in One Place
  – Plan the data flow process
  – Documented IMS to manage data
  – GIS can make it easy to find and interact with data

• Access it, analyze it, visualize it, share it
Thank You!

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