"Development of a Web Based Design, and Construction Bridge Substructure Database"

By Michael McVay[1], Marc Hoit[2], Erica Hughes[3], Thai Nguyen[4], and Peter Lai[5]

[1] Professor, (Corresponding Author), Dept. of Civil and Coastal Engineering, University of Florida, PO Box 116580, Gainesville, FL 32611-6580, Phone: (352) 392-8697, Fax: (352) 392-3394, email: mcm@ce.ufl.edu

[2] Professor, Dept. of Civil and Coastal Engineering, University of Florida, email: mhoit@ce.ufl.edu

[3] Software Engineer, Dept. of Civil and Coastal Engineering, Univ. of Florida, email: ehugh@ce.ufl.edu

[4] Graduate Student, Dept. of Civil and Coastal Engineering, Univ. of Florida, email: ngthai@ufl.edu

[5] Asst. State Geotechnical Engrg, Florida Dept. of Trans., Tallahassee, Fl, email: peter.lai@dot.state.fl.us

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ABSTRACT

The paper reports on the development of a web based interactive database for bridge substructures. Elements include bridge piers, piles, shafts, load tests (Osterberg, Statnamic, and conventional), as well as insitu (SPT, CPT, DMT, PMT), and associated laboratory data. Information is entered into the database over the Internet by the consultants as part of the DOT project activity. For instance, information obtained insitu or in the laboratory is uploaded, checked, and locked, which then makes it available for design. The construction information, which includes all as built information (piers, piles, shafts, etc.) as well as field-testing (boring, load tests, etc.) is subsequently available for maintenance, bridge widening, etc. All the information is uploaded through software (i.e., spreadsheets, gINT, FB-Pier, etc.) employing a XML interface, which includes security. The database is envisioned to follow the bridge substructure from “birth” to “death” with information entered/viewed/download, etc. as part of the workflow.

INTRODUCTION

A number of State DOTs (California, Virginia, Florida, Minnesota, etc.) have established or are in the process of establishing web based Geotechnical Databases. Some include SPT Boring data with laboratory data [VDOT: GDBMS (Geotechnical Database Management System)] others are developing virtual data center interfaces, i.e., links (URLs) to multiple databases, [Consortium of Organizations for Strong-Motion Observation Systems (COSMOS) (*1*) and by the Pacific Earthquake Engineering Research Center Lifelines Program (PEER)]. Since most users are spread throughout a state or country, access to the databases are generally through the Internet. Standard Languages to display the data is HTML and to describe data is XML (eXtensible Markup Language). Existing and ongoing efforts are focused on the development of data dictionaries or format standards for the XML interfaces between software (e.g., gINT, etc.) and backend databases (Oracle, SQL, etc.). Examples of the data dictionaries are TransXML (NCHRP 20-64) (*2*), and AGS-XML (UK) (*3*).

Unfortunately, much of the current design, and construction data for DOT bridge foundations are archived in formats, which may not be queried or mined. For instance, in construction, AASHTOWare's SiteManager (*4*) used by many states stores much of the data in PDF or Tiff formats. The latter is a result of field practices, such as 1) recording construction processes on paper, e.g., pile-driving records (blow counts vs. penetration, pile lengths, etc.); and/or 2) sub contractors performing site work (e.g., pile load testing: Statnamic, Osterberg) with deliverables (i.e., final report) in paper format.

With the development of PDAs and/or field laptops, the electronic capture of pile driving records has now begun (e.g., FDOT Pile Technician Software). In addition, most if not all current laboratory data (e.g., soil classification, rock strength, etc.) and/or field load testing (e.g., Statnamic, Osterberg, etc.) is collected or reduced with spreadsheets (e.g., Microsoft's Excel).

Given the standardization of transportation data (i.e., TransXML(*2*): 1) Survey/Roadway Design, 2) Transportation Construction and Materials, 3) Highway Bridge Structures, and 4) Transportation Safety) the data which is captured and analyzed on spreadsheets (i.e., load tests, lab data, etc.), as well as boring (e.g., gINT, etc.) and construction (e.g., Pile Technician) software, an Internet database associated with a Bridge Substructure, is now viable. The need for this completely integrated database is significant: 1) information collected in the field (e.g., borings) and lab (e.g., classification, strength, scour ability, etc.) may be used by multiple consultants and associated software (e.g., scour: Hec 18 & Hec 20, capacity: Driven, FB-Pier, etc.) in design; 2) provide quality control and assessment during construction; 3) supply input for maintenance, rehab, and scour software (e.g., AASHTOware's Pontiss, FHWA's Hyrisk, etc.), as well as the national bridge inventory, NBI; 4) provide data for updating LRFD resistance factors for piles, shafts, etc.; 5) provide data for research, design software enhancement; and finally 6) provide location for storing information on substructure modification (i.e., bridge widening, repairs, etc.). It is envisioned that the database would follow the bridge substructure from "birth" (design, construction), and through its useful "life." A database, for this complete capture of data is under development by the FDOT and is presented herein.

DATABASE STRUCTURE

Shown in Figure 1 is the layout of the current FDOT's Bridge Substructure Relational Database. The database employs a tree structure with information stored in tables with various hierarchy and interdependence. The Table with the highest hierarchy is the project ID table, Fig. 1, identified by any of the following: 1) project financial number, 2) project name, or 3) project State Job Number. Associated with the Project Tables are 1) bridges, 2) Insitu data, 3) Laboratory data, and 4) Load Test Results, Fig. 1. Note, multiple bridges may be associated with the same project or job number. Within the Bridge Table, Fig. 1, are the Bridge Numbers used in maintenance software, i.e., AASHTOware Pontiss. Associated with a given bridge are its Pier Tables, Fig. 1, which have individual piles and/or shaft tables. Each pile/shaft table contains information (data not shown) concerning as-built (i.e., size, properties, material: steel concrete, etc.). For an "as-built =false" entry in Pile/Shaft Table, Fig. 1, the information is design not the constructed pile/shaft. In the case of "as-built=true," the information was obtained during the construction, e.g., Pile Technician software. Other tables associated with individual "as-built=true" pile/shafts are the Load Test Tables, Fig. 1: 1) Static Top Down; 2) Osterberg bottom up, 3) Statnamic, as well as 4) PDA/Capwap pile driving analysis. Note, the each of the Tables shown in Fig. 1 contains multiple information, which is discussed later.

The Subsurface (soil/rock) information identified as Hole Tables has a similar architecture as Benoit (*5*) used in COSMOS/PEER (*1*). The Hole Tables may have any of the following information: 1) Standard Penetration (SPT), 2) Cone Penetration (CPT), 3) Dilatometer Modulus (DMT), 4) Vane Shear (VST) Tests and 5) rock core or Shelby tube samples. Note, the Hole Tables may be assigned to a given Project ID or multiple Project IDs, Fig. 1. The multiple IDs represent the reuse of the data on the "Life" of the structure, e.g., bridge widening, rehabilitation, etc. Attached to the Hole Tables are Specimen Tables and associated laboratory test results. The latter could include simple tests, i.e., grain size, Atterberg, etc. for Soil Classification (Unified or AASHTO Soil Classification), or the more involved compressibility (i.e., oedometer) or strength testing. In the case of soil strength, both drained and undrained triaxial as well as unconfined compression is available. For rock, the RQD Recovery ratio, the percent recovery, as well as split tension and unconfined compression are recorded. Also recorded during the rock's strength test, is its stress-strain curve, from which the secant Young's Modulus is calculated.

DATABASE SECURITY

There are four levels of user security. The intent is to allow review and acceptance levels for data. The levels are hierarchical and have authority over the lower levels in the tree. The lowest level (0) is considered the data originator and the only account that is allowed to change the data. Figure 2 shows the current security levels for the data.

Users at each level can be assigned access to individual tables and values. The access can include read only and lock or update, read and lock for level 0. Once the lower level is locked, the higher level has review and locking authority over the lower level. However, only the data originator (level 0) can modify the data.

DATABASE ACCESS

The database is written using Microsoft IIS in the .NET environment taking advantage of ODBC connections. All of the file intelligence and security is handled by the web server. ODBC handles the database connection and allows for the use of a variety of databases.

Database interaction is handled completely through the transfer of XML files using the web server. Data is retrieved from the database by first selecting a portion of the data tree and then requesting a download. The selected data is sent to the user as an XML file following the defined XML schema or format. The XML format of the transferred file is flexible. The database has been designed to accommodate a number of different XML schemas. These schemas are defined through a table in the database consisting of XML tags and an XSL style sheet that defines the format of the file. Currently, only the UF-FDOT schema is implemented.

Entering data into the database is also handled through the XML file exchange and the web server. The same format used for sending out from the database is used to enter data into the database. The web server receives the XML file, validates security for each data items and then updates the appropriate pieces of data.

Security is integrated into the structure. Users can be given access to different projects and components under a project. For example, a user may be given access to Bridge 1 under Project 1 with complete access to all data. This same user may only be given access to the pile data under project 2, bridge 3. This access can be limited to specific values in any table.

There is also a history mechanism for the data. Basic data is appended to the table, rather than inserted, and flagged as the current version; older versions are tagged sequentially to allow roll-back. Detailed data such as SPT test data or Statnamic tests are replaced and not appended in order to keep the data storage at a reasonable level.

The database structure has been developed with expansion in mind. The XML file structure is controlled by a table and XSL views. Additional tables can be added following the defined structure of project hierarchy. As an example, the table could be expanded to include retaining walls and roadway projects, Fig. 1.

DATABASE-SOFTWARE INTERACTION

Since the goal of the database is for the user to interact through application software, a number of methods have been created to make this process simpler. There are two delivered tools for interacting with the data: a web browser and a DLL callable from any software application.

The web browser allows users to search the data tree, select a branch and have data delivered to the browser. There are two forms of delivery available, save the XML file, or view the file using pre-defined XSL style sheets. The style sheets allow the data to be displayed in tables and will be important for reviewers and data acceptance. The file save option allows the XML file to be saved to a computer for use by any software application.

The DLL interface was created to simplify the connection for software applications. DLL's are a universal way for any programming language to access the database. Most software applications have a built in programming language. For example, MS Excel, AutoCAD, and many others use VBA (Visual Basic for Applications). Other software applications that are written in C, C++, Java or others can call the DLL and transfer data to and from the database.

The DLL provides two functions: Send an XML file to the Database or receive a data tree, select the requested data and pass the resulting XML file to the software application. The source code for the DLL is also provided as well as examples for connections using Excel and AutoCAD.

Neither the DLL nor the browser is required to interact with the database. Since it is controlled through the web server, all security and interactions are handled by the server and accessed through the XML files. Any application that sends or receives the correct form of the XML files and is authenticated through the user login can access the data.

EXCEL SPREADSHEETS

Excel spreadsheets are typically used for reducing data from the laboratory (e.g., compressibility, strength, etc.) or the field (e.g., Osterberg, Statnamic Tests, etc.). For instance, Figure 3 shows the recording of laboratory soil data, and Figure 4 shows the reduction of a conventional top down static load test. In the latter case, pile/shaft capacity estimates (i.e., Davisson, & Debeer), as well as unit skin friction alongside the shaft were back computed from the strain gages within the spreadsheet. Generally, the data recorded and reduced (e.g., pile/shaft capacities, soil/rock properties, etc.) are printed and turned in as a report during the design or construction phase depending on the activity. However, with the proposed architecture, the information (e.g., Excel spreadsheet) may be uploaded directly by the consultant to the database (Fig. 1) and locked (Fig. 2) for later use on this project or another project.

Presented in Figure 5 is the layout of currently available Excel Spreadsheets for use with the database (input/output). They are divided into four general groups: 1) Design, 2) As Built, 3) Insitu and 4) Laboratory. Generally each group, (i.e., Design, As Built, etc.) is a separate Excel file with multiple sheets (Fig. 5 tree structure) with the exception of As Built. For As Built, separate files are provided for 1) Conventional Top Down Static Loading, 2) Osterberg Bottom Up Loading, and 3) Statnamic Dynamic Loading. The latter is required to deal volume of data, as well as the fact that a different contractor who may not be familiar with other CEI contracts on the project may perform each test. Note, the layout, analysis, etc. of both the Statnamic and Osterberg Spreadsheets have been reviewed by a number of FDOT consultants. A by product of the Excel spreadsheets (Design, As Built, etc.), and the database is the quality control and quality assurance (QA/QC) that the FDOT can exert on consultants, contractors, etc. for successful bridge design/construction.

CONCLUSIONS

The implementation of a flexible and extendable web accessible database has been described. It has been implemented for the Florida Department of Transportation in order to be an active repository for Geotechnical data. The key concept is that the database is accessible through the use of applications. Any application can retrieve or submit data to the database provided the user has the proper security.

The application centric view of the database makes it useable for multiple functions; data warehouse, work flow repository and a research data collection. The data warehouse option moves the concept of electronic storage of data into an active form of storage. All stored data can be actively used by any application without recoding. The

workflow repository option allows the database to be the storage location for data to be shared during project development and construction and maintenance. A Geotechnical Engineer can put their results into the database and allow the structural engineer direct access to the soil data in the form required by their software. Finally, the research option allows owners, researchers and others to query across the database to find, collect and analyze data.

This type of storage for direct use has been the goal of many data storage efforts. The web and current database technology offers the tools and capability to bring this vision into practice. Setting transfer standards will allow the sharing of data and improve the overall quality of results for major engineering projects.

ACKNOWLEDGEMENTS

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LIST OF FIGURES

FIGURE 1 Database structure.
FIGURE 2 Example database security.
FIGURE 3 Spreadsheet for soil description and properties.
FIGURE 4 Conventional top down static load test.
FIGURE 5 Excel spreadsheets for data analysis and database entry.

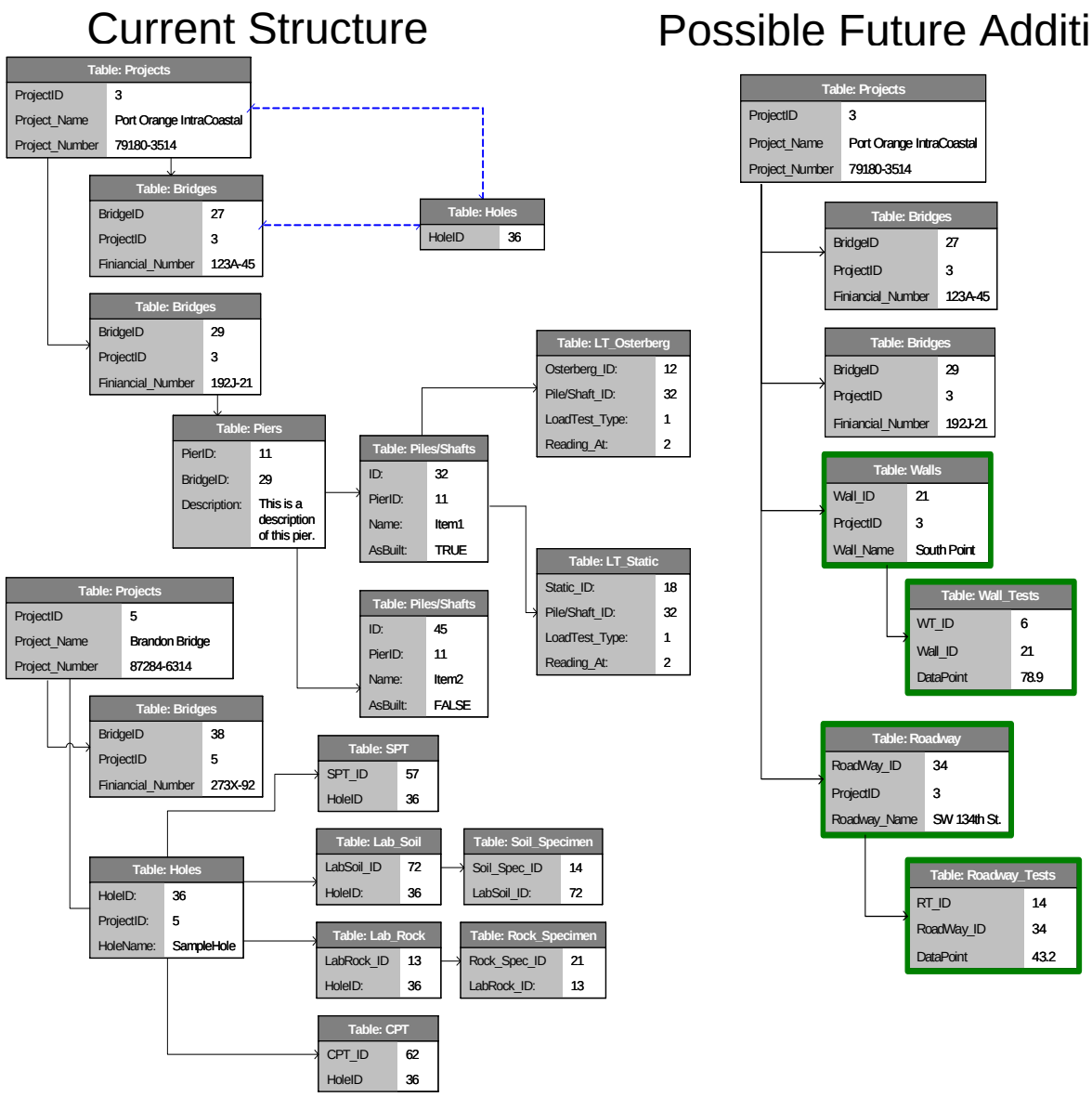

FIGURE 1 Database structure.

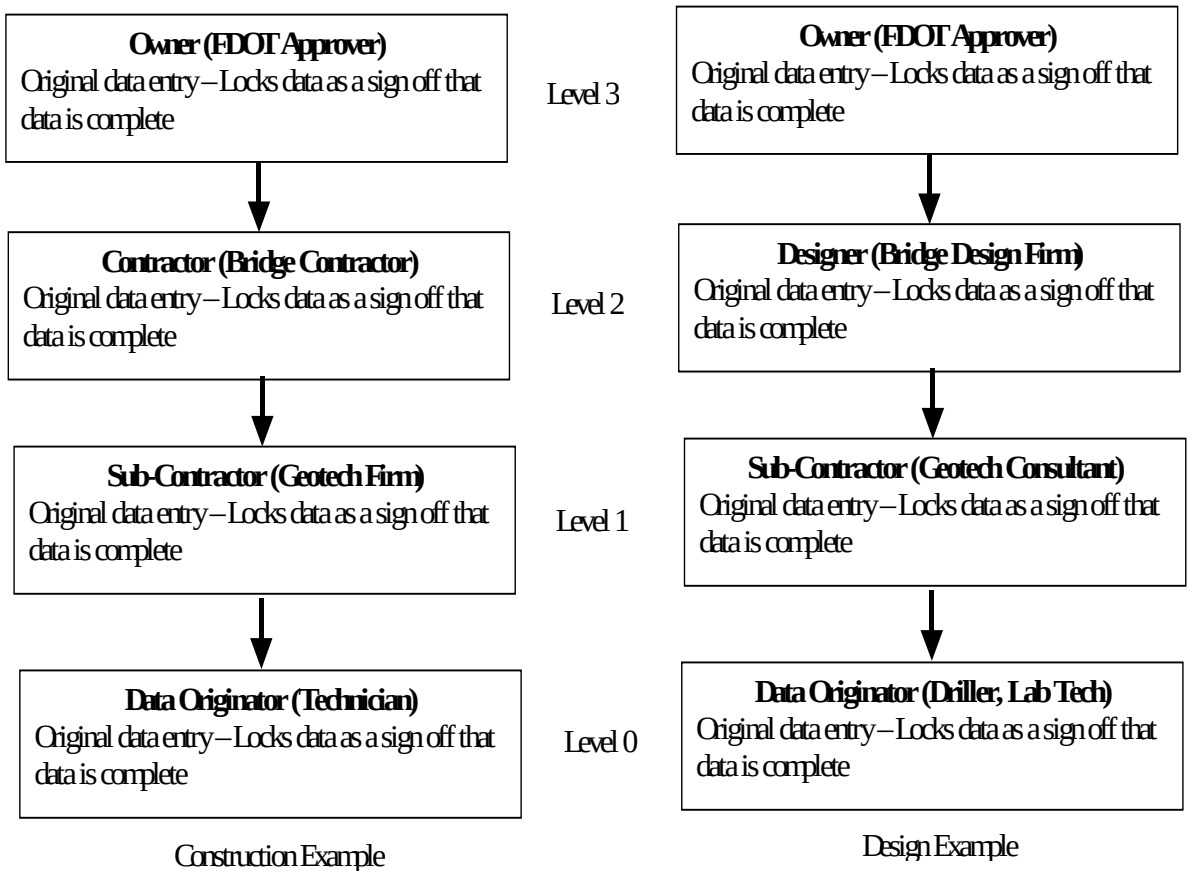

FIGURE 2 Example database security.

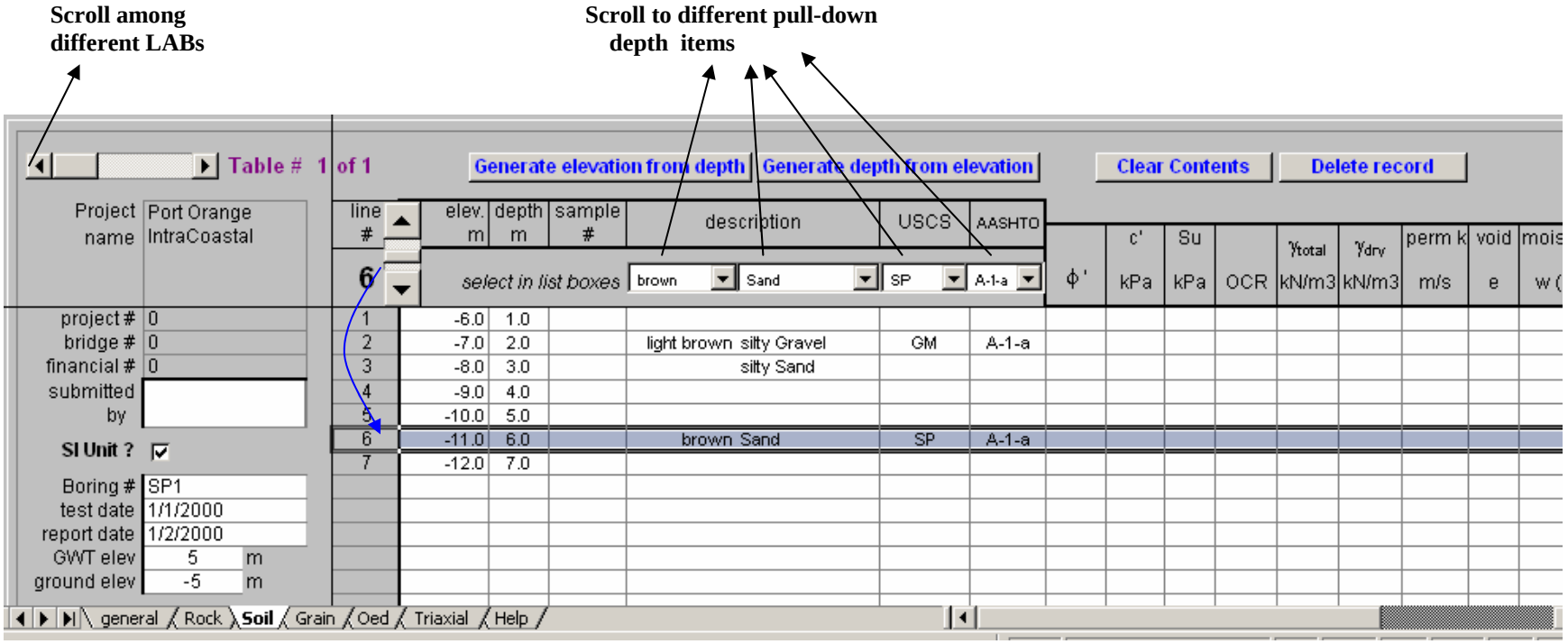

FIGURE 3 Spreadsheet for soil description and properties.

AsBuilt:

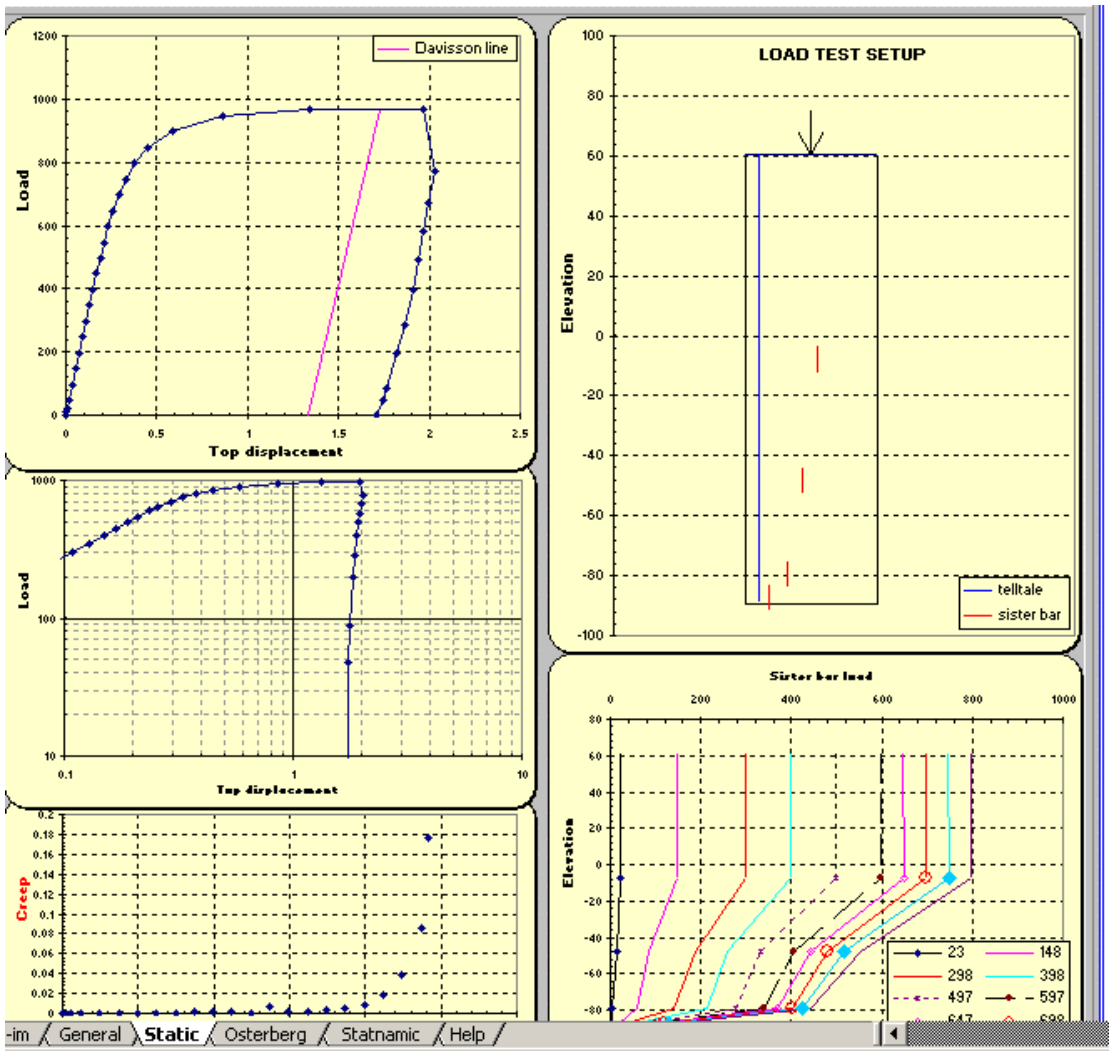

FIGURE 4 Conventional top down static load test.

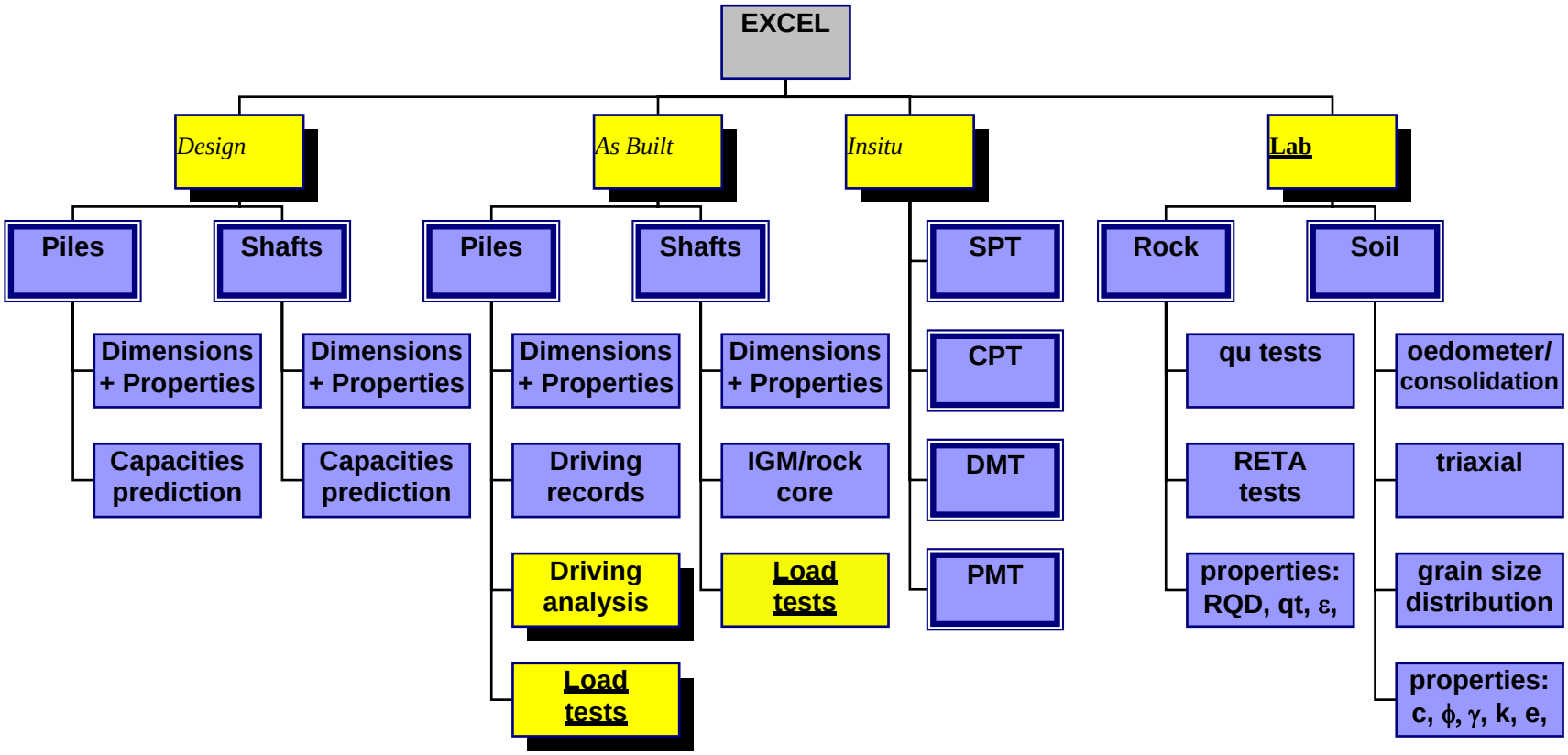

FIGURE 5 Excel spreadsheets for data analysis and database entry.