Project Information Management Systems
in the Deep Foundations Industry*

Deep Foundations Institute (DFI)
Project Information Management Systems (PIMS) Committee
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Introduction

This document provides a general introduction to the concepts and applications of a Project Information Management System (PIMS) to the geotechnical foundations industry. While geotechnical projects have always generated data and created related visualizations and analyses, in the past decade the industry has seen an increase in specifications and owner requirements for formal data management and associated project submissions. At the same time, new and adapted technologies are emerging (the nature and rate of adoption of these differ across regions and owners) that allow increased automation and greater digitalization and generation of data in increasing volumes. The PIMS Committee of Deep Foundations Institute (DFI) was formed to guide the industry in navigating these trends and provide tools to DFI members to maximize the benefits from information management. This document was written by the DFI PIMS committee to provide some non-technical guidance to the industry on these concepts.

The remaining sections of this document include a set of definitions, a discussion of some of the reasons for the geo-foundations industry to encourage the development of PIMS technologies, a brief review of existing technologies and procedures, and a discussion of the future of PIMS use for deep foundations. Future publications will present additional examples, case studies, and other tools to enhance your understanding of these technologies.

Project Information Management System - General Definition

The best way to understand a PIMS is to consider it as a large collection of electronic devices, infrastructure components, data structures, software, and data access and visualization techniques; all amalgamated with a set of quality control processes and organizational methods used to coherently organize the data and information generated during the life of a construction project and disseminate them to project team members and stakeholders.
This description can be summarized as the major functions and goals of a PIMS: collect the data, organize it, assemble it, analyze it, present it, share it, preserve it, interpret it, and archive it for future use.

Data Management Systems (i.e., the family of systems that include PIMSs) have been around for thousands of years since the introduction of the clay Sumerian tablets. The extremely fast-growing computer technology industry allows us to have any information available at our fingertips, anytime, anywhere. This is generally true for most markets and industries; however, the deep foundation construction and geotechnical industries only recently are discovering the value of organizing project data and documents.

Reasons for the geo-foundation industry to encourage the development of PIMSs

There are many types of data that are automatically gathered in near or real time by construction equipment for underground construction; such as drilling rate, rotation speed, tool inclination and location, torque, crowd, grout volume, and grout pressure. Other data collected on these projects include historical data (like documentation, photos, drawings), pre-existing and newly installed geotechnical instrumentation, design and contractual documents, safety and environmental information, QC/QA and acceptance criteria reports.

These data sources can all be combined with technologies (e.g., Geographical Information Systems (GIS) and Computer Aided Design (CAD) 3D models) to be viewed in a common context and serve as part of the overall project record. The intent of a PIMS is to facilitate and maximize the benefits of compiling and relating all these data and to use them to promote and ensure the safety, quality, durability, and sustainability of the deep foundation work performed.

If this is achieved, the benefit of using the PIMS will be shared by the entire geo-foundation industry and in particular:

OWNERS will use a PIMS for proof of validity of the work performed (whenever possible in real-time), reduction in submittal review durations to gain schedule benefits, and to have a complete data set of construction performed.

ENGINEERS, DESIGNERS, and CONSULTANTS will use a PIMS to visualize data, evaluate data gathered, and to confirm design intent is being met. QA and QC processes will be facilitated during construction, and data can be reviewed in shorter time.

CONTRACTORS will use a PIMS to visualize and evaluate the progress of construction, identify and correct issues or omissions, demonstrate that acceptance criteria are met (to support progress payments and project retention releases), to evaluate and justify the construction method, and to evaluate production and any construction related cost for future applications/projects and services.

MANUFACTURER SUPPLIERS and SERVICE PROVIDERS will use a PIMS to understand and improve equipment performance, production rates, and durability of their products.

STAKEHOLDERS (including taxpayers on publicly owned projects) will benefit from use of a PIMS through the execution of projects where more quality control will result in more durable, sustainable and resilient infrastructure while reducing/eliminating possible construction delays and overall cost.

ALL PARTIES can benefit from the inherent ability of a PIMS to reduce liability through data tracking and storage. The specific impacts of a PIMS on liability will be explored in future DFI publications.

The PIMS data being gathered are frequently too numerous to evaluate with standalone database tools, engineering tools, or business tools. The industry continuously develops or identifies new data collection systems for the market and requires expertise to understand these systems. Once the data are gathered, analytics can be used to enable businesses to transform the data into actionable insights.

It is undisputable that data visualization is especially useful for underground construction. The PIMS provides in real-time relevant and complete data to owners, engineers, and contractors in a rapid and understandable manner. Such information will be actionable and will improve the required analysis of the data received and will result in faster but however more analytically finalized decisions. Visualization can help to quickly identify parameters that are out of specification. Data analytics performed in real time can help to identify needed proactive action to help decision makers resolve problems earlier in the construction process rather than reacting to failure conditions.

Existing programs and systems.

According to the general definition of the PIMS given above and examining the history of data collection in the foundation industry, existing data acquisition and visualization solutions can be categorized in 4 basic groups, based on their functions and job site requirements. Each of these categories includes and expands on the functionality of the previous categories.
Basic rig data acquisition (DAQ)

Rigs are equipped with a commercial or proprietary electronic device which collects data. The system consists of some sensors measuring physical processes (e.g., rotation speed, feed, torque, mast verticality) associated with the specific technique to be performed (e.g., borehole drilling, jet grouting, secant piles). A real-time local visualization of the gathered data is generally available in the form of displays or dashboard computer screens; and data (once recorded) can be exported and used to generate activity reports or in downstream analyses. Not all rigs are fully equipped with basic DAQ systems. On some job sites where data collection is not required by the owner, no automated data collection is performed.

Advanced rig DAQ

Several DAQ systems, frequently using different platforms and different geo-techniques, use a network infrastructure to share and transfer collected data. Data are broadcast or transferred in near real-time and, by the means of appropriate software tools, collected by a local database server, a centralized server or even a cloud distributed service, and stored in a database. The data are immediately available to be retrieved from the server/service and analyzed via reports and interactive tools. The raw data files remain available for any DAQ system. Using appropriate data encryption and data verification techniques, systems can reduce data loss, and minimize or eliminate data corruption during the transfer. Networking of the DAQ systems is not common yet.

Basic PIMS

Collecting foundation installation data is only a part of the huge volume of information produced on the project. A basic PIMS collects and makes available some of this information (e.g., documents, environmental data, structural data, and geological data). The PIMS platform and the data collection platform are physically separated and do not interact automatically. The DAQ files (geotechnical or construction data) are post-processed manually or by commercial or customized software tools. The basic PIMS platform can be accessed by the users via a network connection, a web site, or using desktop computer programs. Most of the information is presented using both static tabular and graphical views of the data. While there may be instruments collecting data, there are no real-time data streams in the PIMS.

Advanced PIMS

This is the most advanced and powerful PIMS platform. A state-of-the-art PIMS is logically based and built on a unified vision of the data and the data structures. All components of the system, including the DAQ any other automatic data acquisition system, the manual data generation, the storage/data structure, and the visualization logic and tools, are analyzed during the design phase to produce a well-integrated and performing tool. The advanced PIMS is the one-stop depot for everything known about the project. In addition to being a tool to examine the data, it includes some level of analysis to help with decision-making processes (DSS, decision support system). The platform also interacts with the users, sending out multimedia messages about events, alarms, and availability of new data. In an Advanced PIMS, human activity is minimized in the data collection, organization, and presentation steps through automation. It includes also quality control rules and procedures to further improve the quality and the safety of the project. It is fully integrated with Building Information Modeling (BIM) and GIS technologies and tools.

The users interactively access the advanced PIMS using a web portal interface, available anytime, anywhere.

Current State of the Practice and Future Developments

New technologies are under development that will have direct applications to deep foundations. These may be integrated into existing PIMS structures or represent entirely new methods. Some current and future developments are described below.
Advanced Analytics

Historically, PIMSs have been focused on presenting data (either in tabular or geospatial format). Current and future practices will shift the focus to analyses of collected data. These analyses, performed in real-time or on demand, will identify trends in data to predict outcomes (e.g., use machine learning algorithms to predict excavation rates based on geology), and analyze relationships between metrics to find efficiencies, sustainable practices, and improve quality and safety of many construction activities.

This approach to an "intelligent" PIMS will make use of current and future developments in technologies used to handle "big" data. In this industry, big data refers to the quantity of data (i.e., millions to billions of data records collected from instrumentation and other sources), the diversity of data (i.e., multiple data streams on a project) and the compilation of data across multiple projects (i.e., tracking production quantities for similar drill rigs at multiple sites).

Sensors and the Internet of Things (IoT)

Hardware being developed across this industry and others is trending towards instrumentation. As this trend continues, most or all equipment used in deep foundations technology, including drill rigs, batch plants, and more, will be fitted with instrumentation measuring a suite of metrics at a high measurement frequency. These instruments are or will be web-enabled, allowing them to stream data to digital consumers as part of the "Internet of Things". Taken together, these instruments are able to present a real-time visualization and analysis of all project activities either isolated within a project, or in harmony with other IoT devices (e.g., publicly accessible weather data, reservoir water levels, etc.).

Virtual Reality

Virtual Reality (VR) describes a suite of technologies that allow virtual exploration of a model or dataset in three dimensions. Industry professionals are using VR (via hardware such as the Facebook Oculus) to allow users to virtually "walk" or “fly” through models of dams, structures, galleries, or through walls and the ground surface to view data not physically accessible. When coupled with near real-time data, these VR models can approximate the current position of a drill rig, recent piezometric surfaces, and other transient data.

Mixed/Augmented Reality

Mixed Reality (MR) and Augmented Reality (AR) describe a suite of technologies that enhance a user's experience while at a site. MR (via hardware such as the Microsoft Hololens) allows proposed or other non-existent features to be superimposed on reality, and AR allows data attributes or other items associated with real features to be accessed, visualized, and shared with remote users. MR or AR can, for example, allow access to a geospatial model on a mobile GPS-enabled device (e.g., a smartphone), and provide access to attribute data of a feature at which the device is pointed, or a visualization of subsurface or other invisible features at the user's location. Instrumentation data, for example, can be visualized when the user looks at an associated instrument. This technology will allow PIMS data to enhance site investigation and decision making in real time.

Additional Considerations

Navigating the industry trend towards increased use of PIMS technology may require the community to consider changes in their approach to projects and may also require guidance and personnel with the right skills and tools. These changes may include consideration of data management earlier in the life cycle of a project (i.e., owners may consider it prior to specification development and contractors may consider it prior to building a bid team). DFI members may be interested in hiring computer developers to work and train alongside foundation subject matter experts to make sure that PIMS technology is applied properly and neither the computer nor the engineering elements are disregarded. It is important for the industry to recognize that a new type of specialized personnel will be required as part of the evolution of the geo-foundation industry. While it will be always required to have geotechnical specialized key site personnel (engineers, supervisor, operators etc.), they will need to interface and work in cooperation with computer/electronic specialized personnel with the skills and tools required to collect, manage, connect, analyze, present, and store all these data and be capable of interpreting and meeting new and existing specification requirements to provide the data management systems required to ensure the integrity of the project data. These and other considerations may be discussed in future DFI publications.

Conclusions

Current and future applications of information management technology have been shown to offer many benefits to the DFI community, even when owner specifications do not explicitly require them. The immediate benefits of this approach include increased quality and reduced risk (through increased identification of errors, validation of data, visualization of data in a common context, etc.), and a quick and transparent path towards owner acceptance of construction.

Given DFI's commitment to continually advancing the geo-foundation industry, our interest in promoting and educating the community in PIMS technology goes beyond these immediate benefits. Collecting, compiling, and analyzing project data is becoming necessary to prove that each project adheres to the highest standards. Given that quality assurance and control project requirements/approval should be based on all the information and data collected during the project's life, these activities will provide the following long-term industry benefits:

- Enhancement of safety on the project and of the surrounding structures;
- Improvement of quality and consequently the durability of the products installed;
- Implementation of sustainable and resilient efforts regardless which technology is chosen; and
- Mitigation of long-term project risk.

DFI’s PIMS Committee is committed to developing guidance towards applying PIMS methods to meet these goals.