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Risk management in geotechnical engineering projects by means of an internet-based information and cooperation platform

S. A. Savidis
Technical University of Berlin, Berlin, Germany

F. Rackwitz
Technical University of Berlin, Berlin, Germany

ABSTRACT: Geotechnical engineering can be seen as an information driven discipline. The management of all information is the core of geotechnical project and risk management systems. The key for an efficient risk management system is therefore a system providing right information at right time and right place for the support of regular construction cycles as well as for the handling of exceptional situations which could occur during execution stages of geotechnical engineering projects.

An internet-based information management system has been developed for the purpose of collection, presentation and access of the project key information. Its main components are a document management system and a graphical navigator for the visualization of the most important project information.

The developed information management system has been applied to a large geotechnical engineering project in the city centre of Berlin. By using the internet-based information management system more than 8,500 documents of that project were collected and provided to the users. Especially data from several measurements as essential part of the observational method were integrated in the information system. Several experts from different locations have used the system to prepare discussions, decisions and solutions in the frame of the project and the geotechnical risk management.

1 INTRODUCTION

Planning and execution of civil engineering structures is mainly influenced by the fact that almost each construction is a prototype. That makes the essential difference compared to industrial production processes. Sometimes the structure is similar to one built before, but in this case at least the boundary conditions for construction can differ significantly. The choice of construction materials as well as technology and the structural design are mainly influenced by these boundary conditions.

Geotechnical structures, like tunnels, deep excavations and foundations, are particularly subjected by the variation of the natural boundary conditions. The ground and groundwater conditions are a crucial factor for planning and design of a geotechnical construction. In addition to the natural conditions lots of other factors have to be recognized, such as nearby existing buildings or dynamic loads, which have also to be considered in the structural design.

In the stages of concept design and approval planning in most cases only limited data are available, especially concerning the ground conditions. The following stage of implementation or execution planning, where the planning of all details becomes most important, has to be done under enormous pressure of time, i.e. just in time with construction. In geotechnical projects that kind of procedure can lead to exceptional situations up to disasters, because of limited information or suddenly changing ground conditions.

The Nicoll Highway deep excavation construction in Singapore is an example for a huge geotechnical project which lead to a disaster a few years ago. A deep excavation, 10 to 15 m wide and up to 33 m deep in marine clay ground, was constructed with braced diaphragm walls and a jet grout base slab. In the afternoon of 20 April 2004, the steel brace struts failed and as a consequence the deep excavation collapsed in a total length of about 110 m (Fig. 1).

Fig. 1 Nicoll Highway deep excavation in Singapore just after collapse on 20 April 2004

At the time of the collapse the excavation works reached a depth of about 30 m. Due to the massive ground movement during the collapse also the adjacent Nicoll Highway was completely destroyed in parts. A gas pipeline exploded and resulted in a dangerous fire. Four people died during that tragic disaster.

The reason of the Nicoll Highway disaster was a chaining of several circumstances, negligence's and mistakes. Serious mistakes in communication and management as well as missing and wrong decisions before the disaster, in fact the absence of an efficient geotechnical risk management system, have been analysed as important reasons leading to the collapse (Magnus et al., 2004).

Objective of an efficient risk management must therefore be the reduction of the occurrence probability for every possible exceptional situation. This results in the guarantee of safety for all involved workers on site as well as the guarantee for construction in due time and minimization of total construction costs. The key role in risk management plays the availability of information and the communication as well as the cooperation between all persons involved in the geotechnical engineering project.

2   INTERNET-BASED INFORMATION AND COOPERATION PLATFORM

2.1   General Aspects

The minimization of the occurrence probability for every possible exceptional situation during geotechnical on site execution demands for the following rule: right information at right time in right place. Especially the detailed knowledge of the actual state of each part of the construction as well as the soil-structure interaction is a crucial part. Very important are also short and efficient communication channels in conjunction with clearly defined responsibilities.

Fig. 2 shows the schematic workflow of a typical geotechnical engineering project starting from the idea of the project going through all stages of planning, evaluation and construction and finishing with the utilization of the project. It can be seen from Fig. 2 that there are lots of cross references and interactions between the several stages of a project. Not shown are the numerous persons involved in such a project.
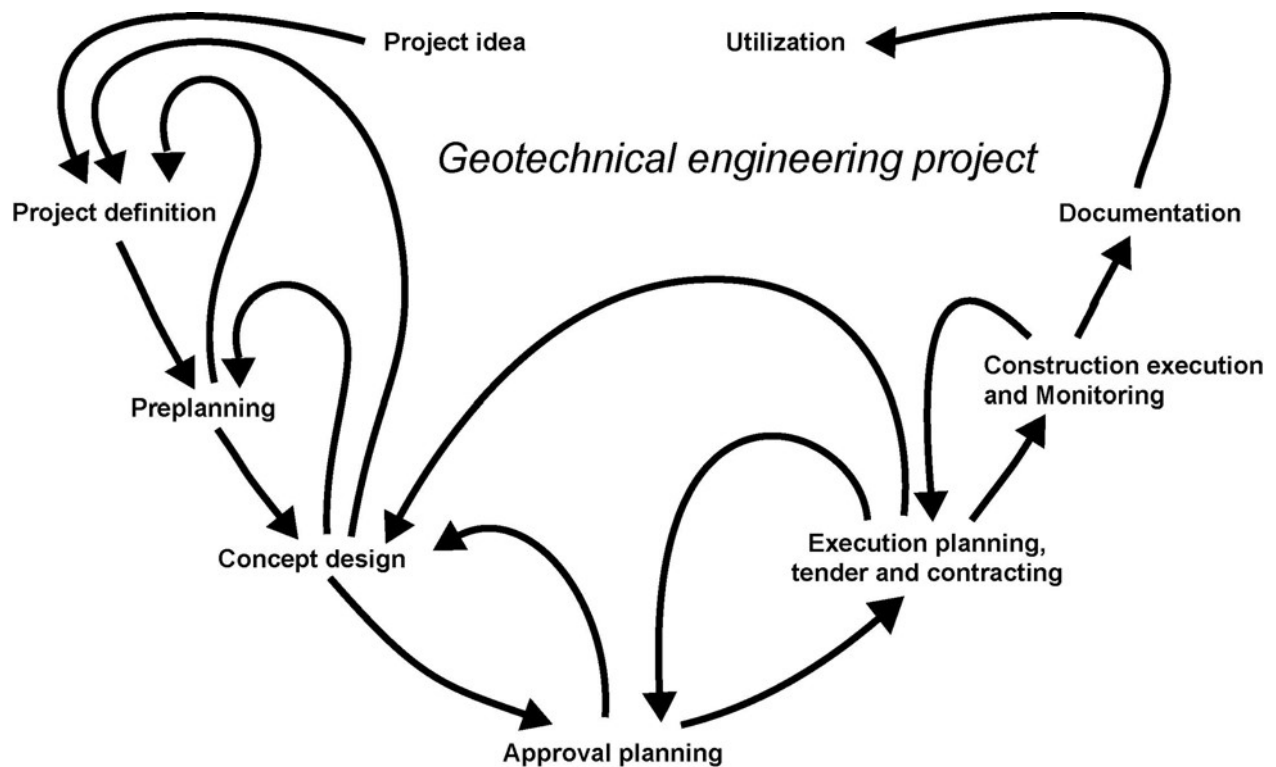
Fig. 2 Workflow of a geotechnical project from the project idea till the utilization

Unlike other civil engineering projects there is the need for extensive monitoring with measurements during execution of challenging geotechnical projects. The monitoring, i.e. the measurement of several important physical values during and after construction, is the core of the geotechnical observational method. The method itself can be traced back to the work of Terzaghi (Einstein, 1991) and is nowadays part of many geotechnical standards (EN 1997-1, 2004).

The geotechnical observational method comprises supervision and control of soil-structure interaction through measurements, such as forces and displacements, in the ground and on the structure. Objective of the method is the sound assessment of uncertainties and geotechnical imponderabilities with planning and design as well as during construction. Challenging geotechnical projects with difficult ground conditions require the application of the observational method.

State of the art is the independent measurement of different physical values with various structural components and in the ground. Based on the measured data mostly a manual evaluation will be done. The storage of the data is mostly done with evaluated printouts in separate folders. But nowadays a rapid evaluation and interpretation of the data becomes more and more important to get the possibility for immediate decisions. Rapid searching has to be possible to find the necessary information at right time.

2.2 Requirements for a Geotechnical Information- and Management System
In geotechnical engineering projects accumulate numerous reports, plans, construction data as well as data from several measurements which have to be collected, updated, evaluated and stored in an appropriate manner. All the data are the basis of decisions during execution. Quality assurance is also based on such data and necessary for the avoidance of exceptional situations and disasters. It is important to have all data available for every person which has the authorization to use them. The date have to be provided wherever the person remains and whenever the person has time to look into the data. The use of a database is therefore a requirement. Traditionally small and medium construction companies have a working environment which consists of a heterogeneous collection of engineering software applications and 'standard software' including office software for processing of the necessary information.

An internet-based information and cooperation system is able to provide these requirements and makes it possible that each authorized user can benefit from the system. Only an internet connection and an internet browser software would be necessary to have all current data available. A graphical user interface providing a simple overview of the project and consisting the main components of the project is also necessary to find the right information.

The acceptance of such a system in practice mainly depends on a cost-benefit analysis. Important is a simple and intuitive use of that system. The choice and extension of project specific key words has to be possible. In addition the practice demands for security and legal aspects, such as backups, data confidentiality and authenticity of all embedded information in the database.

Summarized are in the following the main requirements for an internet-based information and cooperation system:

- Access to all essential project information (ground data, plans, construction protocols, measurement data, site pictures etc.)
- Integration of the monitoring
- Intuitive use of the system
- Clarity and Clearness
- Internal and external access to the system from arbitrary places
- Possibility for project specific simple modifications
- Security aspects (backup, data confidentiality etc.)
- Legal aspects (data authenticity etc.)

2.3   Theoretical Modelling and Implementation

The theoretical model of the information and cooperation platform is based on a hybrid two-level information management system (Schley et al., 2006). The first, document-based level builds a semantic describing resources-based information management by means of internet-based technologies. These information resources have to be integrated into a system, which enables simple locating of information and gives transparency to the user. Therefore a model-based information system was developed in the second level incorporating a graphical user interface – *the graphical navigator*. The information system comprises the key information of a specific project.

The internet-based graphical navigator offers the necessary information to all internal and external involved persons of the project at the same time. It gives a quick visual project overview, which is especially important for occasionally working experts. The available data consisting of plans, protocols etc. is reduced to the key information in the graphical navigator views. A timetable view allows the user to check past, present and future activities and to detect any time delay and its consequences.
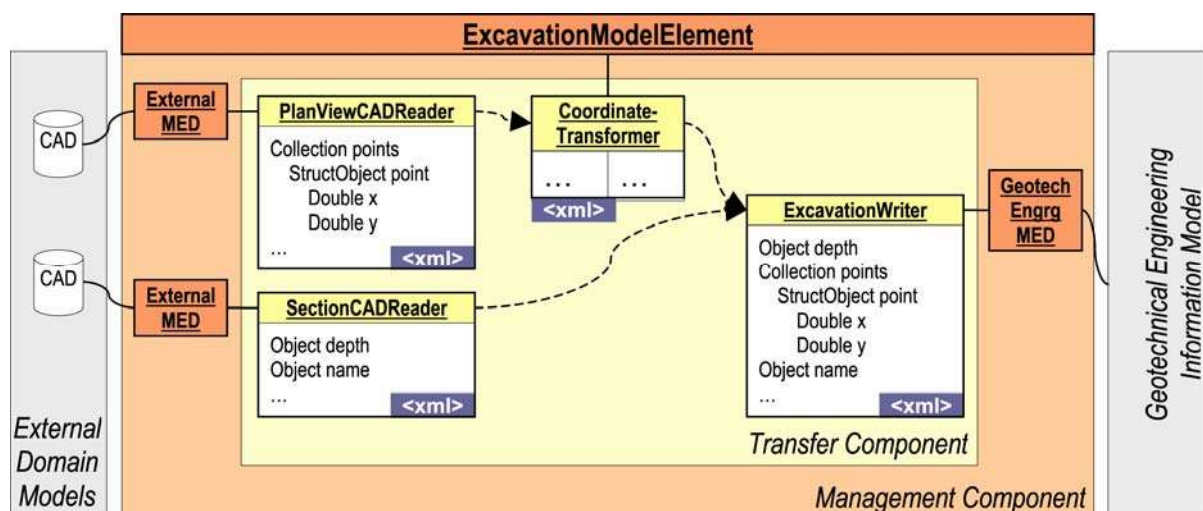

Fig. 3 Model management and information transfer between external models
(Schley et al., 2006)

The information model consists of three components. One component maps the construction objects of a project. The second one maps the execution processes and the third maps the organizational structure of the project. Comprehensive relations between these components characterize for instance the responsibility for each construction object, their validity period, the linkage between activities, responsibilities and construction objects.

The model management consists of a transfer as well as a management component, which is illustrated in Fig. 3. The management component handles and controls the relationships between the elements in the geotechnical model and the external domain models.

In practice there are in general many different models applied. Each model represents very specific parts of the whole project and from very different views, such as ground model, structural model, timetable model, monitoring model etc. These different models are implemented in numerous software applications, which work usually parallel and independent of each other. A transfer component is therefore necessary to link between these various external models and the geotechnical engineering model.

3   PRACTICAL APPLICATION EXAMPLE

3.1   Project Description

The web-based multilevel information management system has been applied for the first time in the frame of a large geotechnical engineering project in the city centre of Berlin. Main part of the project was the construction of a deep excavation with a total surface area of about 22,000 square meters and a length of about 270 m. The project had to be executed within eight months only. The excavation was divided into four parts to minimize risk as well as to end up with an efficient construction process in the required time schedule.

One of the major problems for design and construction of deep excavations in Berlin is the very permeable sandy soil. The groundwater level is about three till five meters below ground surface and groundwater lowering is not allowed. Therefore wall-slab constructions are used for most deep excavations in Berlin (Savidis & Rackwitz, 2004).

Diaphragm walls with tie backs and jet grouting slabs have been used for the construction of the four parts of the excavations. In total approx. 750 m diaphragm walls with 0.6 and 0.8 m width and up to 23 m depth were constructed. In parts of the excavation area inclined struts had to be used instead of tie backs.

Fig.4 Partial view of the deep excavation in Berlin, Germany, during excavation works in the deepest excavation pit

A jet grouting base slab with a thickness of 1.3 m was constructed in a depth of 20 m below ground surface level. Tension piles with small diameter (GEWI-piles) were used to prevent uplift in one part of the excavation. The excavation base level varied from 13 to 17 m in the four parts of the excavation pits. Slurry walls were constructed to separate the excavations from each other.

Fig. 4 gives a partial view to the project after construction of the diaphragm and slurry walls. The excavation works in the deepest part of the excavation are in progress. On the left side in the figure the heads of the tie backs can be seen about 4 m below ground surface and in a distance of 1 m.

A nearby train line and a metro tunnel underneath made it necessary to establish an additional monitoring program to measure and to control the vibration from site works and its influence on the existing structures.

3.2   Application of the Information and Cooperation Platform during Project Execution

The first practical application of the information and cooperation platform was prepared and realized in close collaboration with the contractor of the excavation works. At the beginning the limitations for this first application was agreed because of the very tight schedule and the large size of that project.

Therefore the web-based graphical navigator together with a simplified model without process and organizational components has been used to manage data and information on the construction site. The structure of the ontology consisting the key words was jointly developed and discussed with the project management and quality control personnel of the contractor and it was specifically related to the excavation project.

A number of different classes of data and documents arise from the construction phase of such a huge geotechnical engineering project. It was decided to limit the class of documents within the information system to the following types: construction production protocols for walls, slabs, anchors; plans; ground investigation reports; data and documents from several measurements during and after construction. Fig. 5 represents a schematic view of the content of the document management system and its linkage between user access and available information.
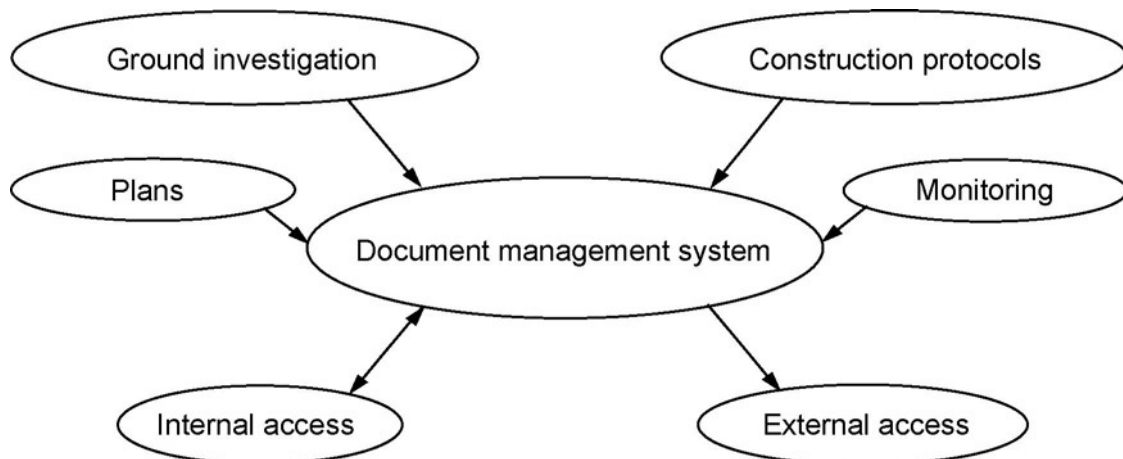

Fig.5 Document management system as part of the information system

Fig.6 is a screenshot of the internet-based information and cooperation platform for that excavation project showing the main window of the document management system on the left side in the background, a sample plan in the middle and on the right side a part or the graphical navigator.
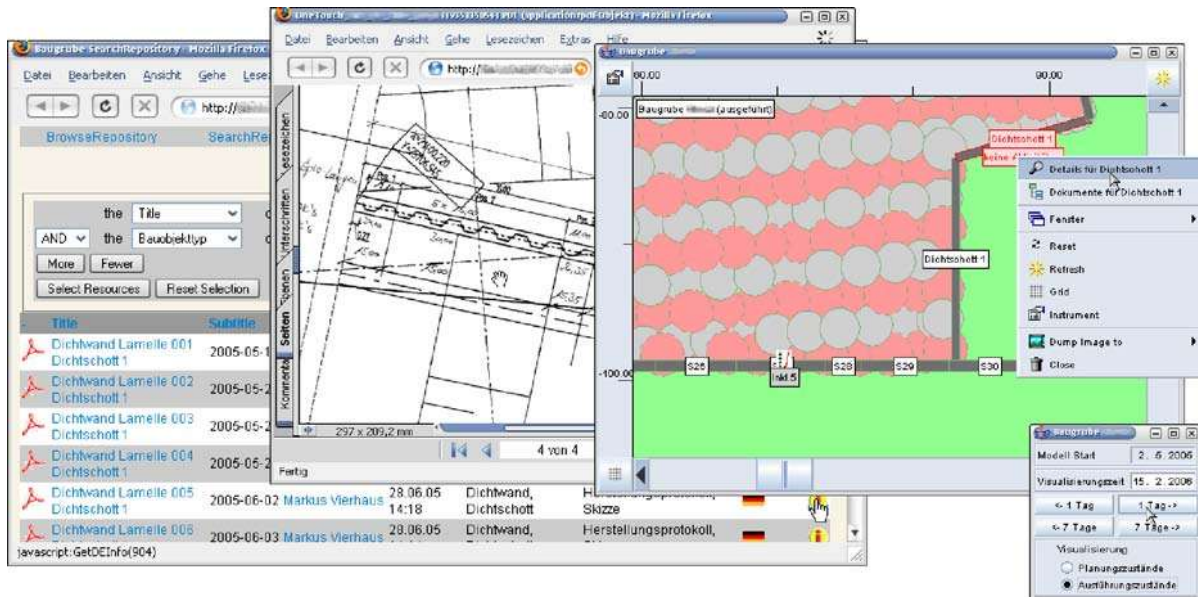
Fig.6 Screenshot of the internet-based information and cooperation platform for a deep excavation in Berlin, Germany

In the frame of the geotechnical observational method several monitoring systems were used in that project to control the soil-structure interactions during and after the construction process. The data from these measurements, such as anchor forces, wall deformations, changes in soil density and ground water level inside and outside the excavation pits have been integrated into the information system. All these data are very important for quality control, risk management and decision making on the construction site. Also new data from ground investigations during the construction works have been continuously included in the information system.

Most documents were stored in PDF-format to guarantee the authenticity of the data as a requirement of the contract between contractor and the building owner.

3.3   Experiences from the Practical Application

The information and cooperation system was frequently used by the contractor's project and risk management personnel. In addition guest access was provided part time to sub contractors and consulting engineers to solve specific problems during the construction time.
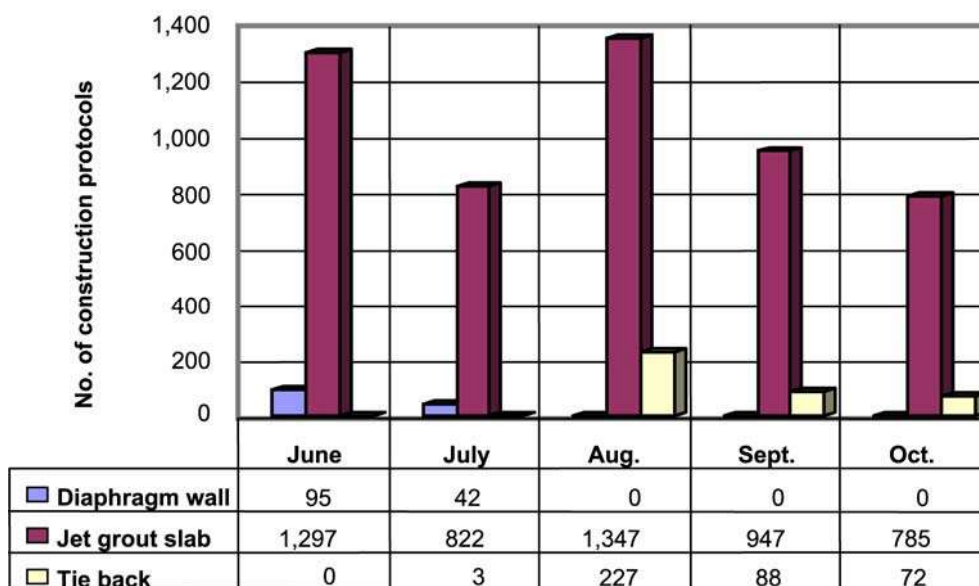

	June	July	Aug.	Sept.	Oct.
Diaphragm wall	95	42	0	0	0
Jet grout slab	1,297	822	1,347	947	785
Tie back	0	3	227	88	72

Fig. 7 Number of documents concerning different geotechnical installation processes in the information system

695

Questionnaires were developed and distributed to the users to get their feedback for the evaluation and subsequent improvement of the system. Especially the evaluation of the questionnaires reflected the advantages of the use of that system in practice. After recent final completion of the excavations all data serve now as project archive and are used for further evaluation in research as well as in practice.

Fig. 7 presents the production protocols and documents from the construction of the main components of the deep excavation, such as diaphragm walls, tie backs and jet grout base slab. It can be seen from Fig.7 that a huge number of only these specific types of documents occurred during the execution stage of the project. In total more than 8,500 documents were managed and provided by the information and cooperation platform.

4 CONCLUSIONS

Continuously increasing complexity of geotechnical engineering projects worldwide demands for an appropriate information, cooperation and risk management tool to support the personnel responsible for the successful realization of such a project. The occurrence probability for every possible exceptional situation during construction can be minimized if and when every responsible person involved in the project can have access to the current project key information at any time and any place. An internet-based information and cooperation platform provides all the necessary information.

The first practical application of a newly developed internet-based information and cooperation platform was realized in the frame of a large deep excavation project in the city centre of Berlin. The complexity of the project required the use of an efficient information and risk management system.

The very positive experiences from that application show the acceptance and the benefits of such a tool in geotechnical engineering practice. Further development of the platform orientates on the requirements from practice and during first application in the above mentioned project.

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