TSINGHUA SCIENCE AND TECHNOLOGY
ISSN 1007-0214 22/67 pp132-137
Volume 13, Number S1, October 2008

Use of Internet Technology for the Improvement of Execution Management in Geotechnical Engineering Projects

Peter Degebrodt, Marcus Mejstrik, Frank Rackwitz**, Stavros Savidis,
Frank Schley†, Klaus-Peter Holz†

Chair of Soil Mechanics and Geotechnical Engineering, Berlin Institute of Technology, Berlin D-13355, Germany;
† Lehrstuhl Bauinformatik, Brandenburg University of Technology at Cottbus, Cottbus D-03044, Germany

Abstract: An internet-based information and monitoring platform for the specific requirements of geotechnical engineering projects is presented. The platform is based on a hybrid-model approach consisting of a model-based information management system and a resource management system, the latter also referred to as DCMS. Project key information can be accessed via the main user interface, the “graphical navigator”. The graphical navigator provides also a direct access to additional information in the DCMS. Prompt reaction in exceptional situations as well as in daily work gets an extensive support. In practical applications it has been proven that this platform seems to be an adequate tool especially for risk assessment and management in geotechnical engineering projects. Components and advantages of the platform as well as experiences from the applications are presented and discussed in the paper.

Key words: information & execution & risk management; internet; monitoring; geotechnical engineering

Introduction

Prompt access to current information is essential during execution of complex construction projects with high risk potential and a tight financial as well as time schedule. Moreover a close cooperation between experts working at different places is necessary to successfully carry out a project.

In most cases, the project execution is not based on an efficient cooperative team work. The basis for a successful cooperative team work is the synchronization of the level of all relevant information. The conventional procedure comprises time-consuming meetings and engineers have to work through protocols, drawings, and other documents. In most cases only parts of a document are relevant for the own work and decisions. By digitizing this procedure, important working steps could be made more efficient.

The usage of information systems can contribute to the improvement of information handling in a construction project. In other industries the use of information systems is widely sophisticated and has highly affected the project information management. The central internet-based allocation of information and fast access to information leads to a significant enhancement of efficiency. Nowadays broadband internet-connections and thereby the wide use of information systems became competitive. Being part of this development plays an important role for any modern acting company, not only in the building construction industry.

1 Fundamentals

1.1 Risk assessment and management in geotechnical engineering

Geotechnical engineering projects are different from other construction projects, because of a high risk for

Received: 2008-05-30

** To whom correspondence should be addressed.
E-mail: frank.rackwitz@tu-berlin.de

the occurrence of exceptional situations. Exceptional situations can occur mainly due to high uncertainties of the geological and hydro-geological nature of soils. The main target is to reduce the impact of exceptional situations, which are often followed by a disruption of the construction processes and an increase of estimated costs.

The monitoring concept as part of the quality management is a fundamental element in geotechnical construction projects. The monitoring is also the basis of the "geotechnical observation method"[1], which became part of the current German and European code of Standard[2,3]. The method includes the observation and control of the soil-structure-interaction via measurements of physical values, e.g., forces and deformations, in order to estimate uncertainties and geological risk during the construction phase.

In geotechnical engineering projects the extensive recording of data during the execution phase is inevitable and these data is often interpretated by experts. Because of a tight time schedule for finishing a construction project, as part of most contracts, a fast evaluation and exact interpretation of data becomes high importance for a fast reaction in exceptional situations. So a fast exchange of information is inevitable necessary. Therefore the use of internet-based technologies to significantly support the quality and the promptness of reactions in geotechnical execution management is quite useful and necessary.

1.2 Information management in the construction industry

Engineers have to deal with a large amount of different information which ranges from the planning stage to the execution stage. Throughout all stages the high demand on quality assurance forces the contractor to manage a large quantity of documents, plans, protocols and ground investigation data. Many construction companies still do this on a very traditional way — they file documents. For large projects, this system is very limited in terms of finding needed information in an acceptable time. At large construction sites several thousand documents can be accumulated easily. As a consequence a huge amount of time is spent for fast access and distribution of information.

The distribution and collection of information over the internet during the manufacturing process is well developed in many other industries. But many parts of the construction industry, especially medium and small construction companies, still don't participate from the use of internet-based technologies.

Integrated information and communication systems for supporting processes in the construction industry are not as much accepted and common as in other industries. Nevertheless, electronic document management systems are more and more used, especially in large engineering projects[4]. Companies using those information and communication systems consequently can achieve a significant advantage compared to other companies. This effect can be noticed particularly in multi-partner construction projects[5,6].

2 Key Information: Hybrid-Model Approach

A central information and monitoring platform is an alternative to conventional procedures in geotechnical engineering projects. Therefore an internet-based information and monitoring platform for the execution of geotechnical engineering projects has been developed in the frame of a joint research project by TU Berlin and BTU Cottbus.

The requirements for the platform have been worked out with an extensive analysis of construction processes in geotechnical engineering projects. In terms of the information handling it proved to be necessary to separate key information, i.e. main information, from the heterogeneous database.

The basis of the information and monitoring platform is a management system that comprises two principally different components: the model-based information system and the resource management system DCMS. Both are put together in the hybrid-model approach. Figure 1 shows the general structure of the system containing these two components.

The model-based information system maps a geotechnical engineering project with its key information. This key information is mainly time-dependent and an important geometrically information for construction objects. Also organizational units, a process component and a monitoring component are parts of the model. The model is capable of mapping a wide range of elements used in geotechnical engineering projects with its key information in their needed granularity.

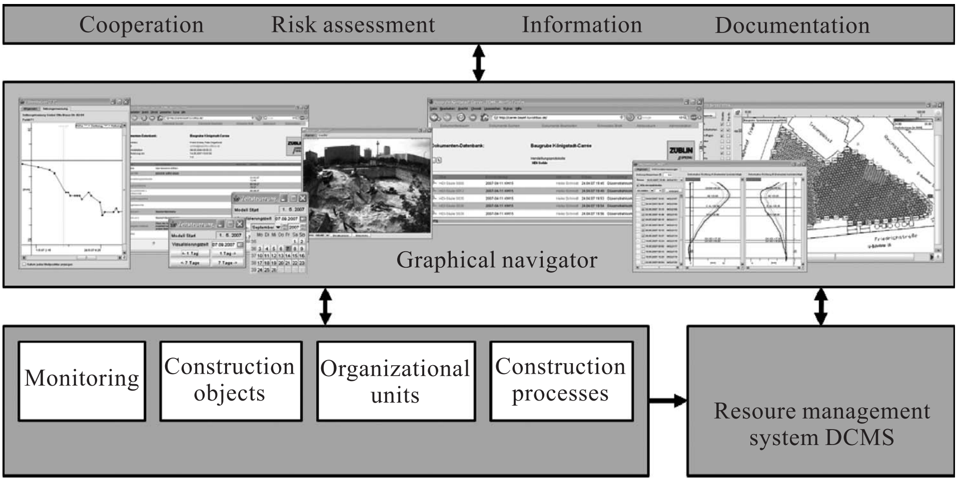

Fig. 1 Structure of the internet-based project platform

The information system has been modelled using the unified modelling language (UML) and has been entirely implemented in JAVA[7]. Figure 2 shows the essential elements of the component "construction object".

A graphical user interface (GUI) called graphical navigator (GN) has been developed to present the key information and tools to the user. It is the central utility for the work with the model-based information system and gives the user the possibility to easily access project related information. The engineer involved in a construction project can use this graphically presented key information and tools to assess the state of construction at any time and any place. Different monitoring tools depending on the specific project requirements can also be integrated into the GN to present the results of measurements.

The resource management system DCMS is used to manage and to provide access to all project related documents[8]. A document stored in the DCMS can be seen as a container of heterogeneous information of different granularity. Dissolving all this heterogeneous information in its single information would not be helpful. For risk assessment and quality assurance on site, the needed information is only the key information which can be directly accessed via the GN.

3 Practical Application

An application of the system has been judged to be very important to proof the concept of the hybrid-model approach as well as to gain experiences with the use of the platform. The construction company Züblin Spezialtiefbau GmbH, Berlin, has been incorporated as a powerful partner. The first practical application of parts of the developed system was started with the construction project "Alexa" in the city centre of Berlin, Germany. The experiences were very positive. So all participating parties decided to use the platform in the second (Königstadt-Carrée) and the third (Spreedreieck) geotechnical engineering project in Berlin, which will be reported here.

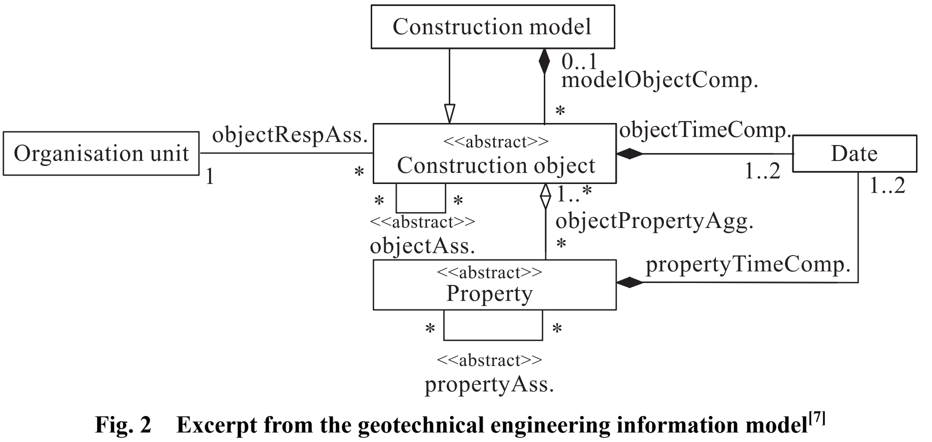

Fig. 2 Excerpt from the geotechnical engineering information model[7]

3.1 Project data

The project "Königstadt-Carrée" was a deep excavation pit with an area of approximately 3300 m^2 and a depth of 13 m. It was supposed to be finished in four months only. The water level was about 3 m below the ground surface. The ground conditions mainly consist of sandy soils, fine to coarse sand with some gravel and sandy silt. These conditions can be seen as being typically for the central area of Berlin. Streets and an existing multi-storey building surrounded the excavation site. Diaphragm walls were chosen as the vertical sealing against the ground water and a deep jet grouting slab as a horizontal sealing layer of the excavation pit. One row of tie-backs was used to retain the diaphragm walls.

The project "Spreedreieck" was a deep excavation with a higher risk level because of surrounding tunnels close to the diaphragm walls. Because of that a bracing system inside the excavation was necessary. The depth of the pit was about 10 m with more difficult ground conditions as in the "Königstadt-Carrée" project.

3.2 Working with the model-based information system — GN

In Fig. 3, the main window of the GN of the project "Spreedreieck" is shown.

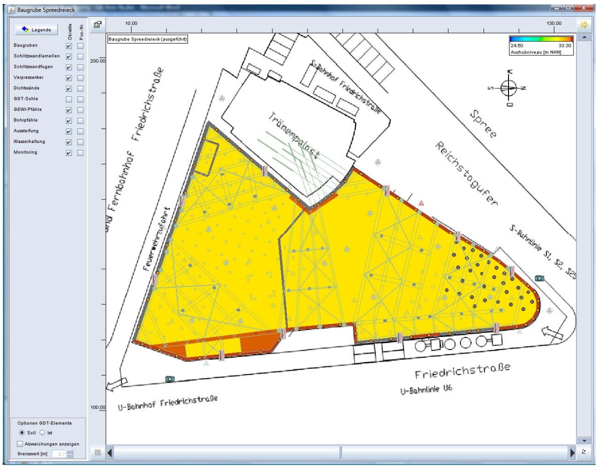

Fig. 3 The graphical navigator of the project "Spreedreieck"

That main window shows the schematically drawing of the construction site. It includes the diaphragm walls, piles as well as symbols for the installed monitoring elements. The surrounding streets and main structures of the construction site are displayed in the drawing for a better orientation. All construction objects are displayed with their basic geometries only. Whenever new types of construction objects occurred during the construction process, they have been integrated into the information model, including the objects for monitoring. Two web cams were installed to report the progress of work. Pictures from the web cams were taken and stored automatically into the DCMS.

Every object can be selected in the GN and additional key information like the more detailed geometry of an object, e.g. the depth of a diaphragm wall element or the manufacturer with its contact information, can be recalled from the information model. The user can automatically generate a search for all stored documents in the DCMS connected to the selected construction object.

A time-control window (not shown in Fig. 3) allows the user to specify a certain date of interest. By doing that the state of the construction process at the specified date is displayed in the GN. This feature allows the site engineer to make up a complex picture of what happened when and where on the construction site.

In Fig. 4, a detail of the project "Königstadt-Carrée" is shown on April 24th, 2007. The construction of the diaphragm walls is finished and the construction of the deep jet grouting columns were started.

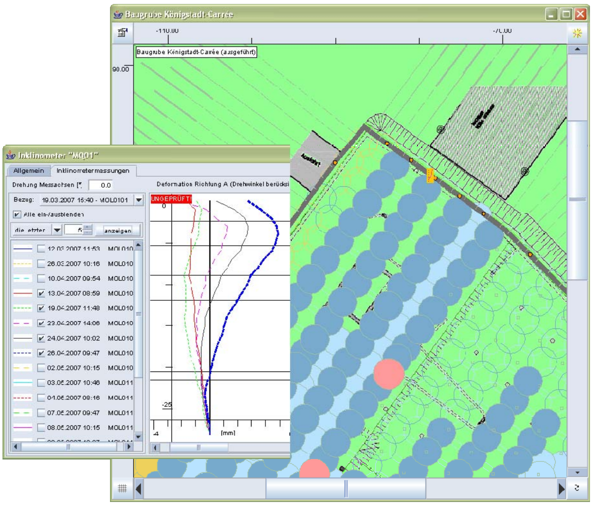

Fig. 4 Selected inclinometer MQ01 with a diagram of its measured displacements

Different colours of a construction object represent different phases of construction. The inclinometer "MQ01" was selected in Fig. 4 and the measured wall displacements of this monitoring-object are shown in the front. Beside wall inclinometers additional monitoring tools have been integrated into the GN, i.e. settlement pins and ground water gauges. For the site engineers it was of great advantage to have a simultaneous view of the displacements of a certain inclinometer, the degree of completion and activities on site at the specified date.

3.3 Working with the resource management system DCMS

A screen shot of a DCMS internet-page is shown in Fig. 5. It shows the document tree with folders for protocols of anchors, daily reports, and others. In addition, links to installed webcams are placed within the document tree too. The user can simply click on a document of interest, which will be opened within a pdf-viewer. The usage of the pdf-file format to store a protocol in the DCMS is appropriate because of the fact that a pdf-file cannot be changed. That is important due to safety requirements by the involved construction companies.

Every action on the DCMS is logged for safety reasons. Up- and down-load as well as the updated of documents is monitored and can be retraced by the administrator if necessary. Because of the high number of documents, it is essential to "mark" an uploaded document for a later search with its key characteristics.

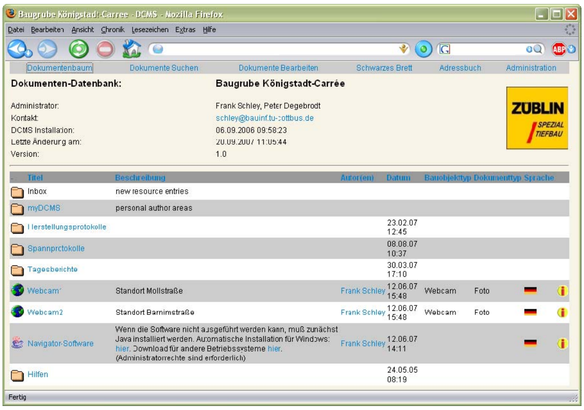

Fig. 5 Document management system — DCMS

During the construction project "Königstadt-Carrée", in total 845 protocols and documents have been managed by the DCMS (Table 1). A single document may consist of several sheets. Filing of such a high number of paper-form documents is time-consuming and searching for an information might be difficult.

Table 1 Number of documents in the DCMS of the projects "Königstadt-Carrée" and "Spreedreieck"

	Total	Other documents	Piles	Ancors	Injection elements	Diaphragm walls
Spreedreieck	3267	298	187	10	2710	62
Königstadt-Carrée	845	74	60	148	536	27

As expected, after a short time of getting used to the platform, the site engineers took advantage of the new possibilities. The effort of uploading all documents in the DCMS was about four hours a week in average.

During the execution of the geotechnical engineering projects all accumulated paper-form protocols and documents have been archived in the DCMS. For both mentioned projects the information model was adapted to the site specific boundary conditions. The construction objects for the monitoring equipment have been included into the model. Inclinometers were used in both projects for the measurement of horizontal displacements of the diaphragm walls.

3.4 Risk assessment and quality assurance

The platform has been used to analyse a certain source of risk potential. While working on the deep jet grouting slab in front of the nearby building at the project "Königstadt-Carrée", the impact of construction works on the wall displacements and the settlements of the nearby building was analyzed using the platform. It was very helpful to evaluate and validate the measurements by means of the tools of the platform.

Another important factor for the practical adoption is the timesaving effect. Existing information from different sources of the construction site was used simultaneously for risk and quality assessment. Furthermore, the automatically taken pictures from the two web cams can be used as evidence of what happened.

4 Conclusions

The internet-based information and monitoring platform with its hybrid-model approach is meant to support the daily work of engineers involved in geotechnical engineering projects and working at different locations, cities or even countries. With the presented platform a web-based utility has been developed, which is capable to be used for risk assessment and quality management. The user interface, the graphical navigator, presents only the project key information using several appropriate tools. Engineers are able to make up a detailed picture of the project's construction progress.

Up to now the platform was successfully applied with three projects. After a short time of practice, all participants were able to use the platform in their daily work. These applications proved that the developed hybrid-model approach is well suited to cope current deficiencies in execution management of geotechnical construction projects. A noticeable timesaving effect was detected during the practical adoption.

In the frame of the aforementioned projects the access to the platform was strictly restricted. It was necessary mainly due to the fact that sensible project details were stored in the DCMS and in the information model. New requirements are expected when using the platform in a multi partnership project with several industrial companies involved.

Acknowledgements

The presented work was supported by the German Research Foundation (DFG) in the frame of the DFG Priority Program "Network-based Co-operative Planning Processes in Structural Engineering" which is gratefully acknowledged here. Furthermore, the authors want to thank Züblin Spezialtiefbau GmbH for the close collaboration during the application of the platform.

References

[1] Riedmüller G, Schubert W, Semprich S, eds. Die Beobachtungsmethode in der Geotechnik. Konzeption und ausgewählte Beispiele. Beiträge zum 14. Christian Veder Kolloquium, 1999: 246. (in German)

[2] DIN 1054. Subsoil. Verification of the safety of earthworks and foundations. Beuth, 2005. (in German)

[3] Eurocode 7. Geotechnical design – Part 1: General rules. prEN 1997-1, January 2004.

[4] Björk B C. Electronic document management in construction – Research issues and results. *Electronic Journal of Information Technology in Construction*, 2003, **8**: 105-117. http: //www.itcon.org/2003/9.

[5] Sulankivi K. Benefits of centralized digital information management in multipartner projects. *Electronic Journal of Information Technology in Construction*, 2004, **9**: 35-63. http: //www.itcon.org/2004/3.

[6] Back A, Seufert A. Computer supported cooperative work (CSCW) – State of the art und zukünftige herausforderungen. *HMD Praxis der Wirtschaftsinformatik*, 2000, **37**(213): 5-22. (in German)

[7] Holz K P, Savidis S A, Schley F, Rackwitz F, Mejstrik M. Berücksichtigung von Ausnahmefällen bei der kooperativen Bearbeitung von Projekten des konstruktiven Tiefbaus. In: Rüppel U, ed. Vernetzt-kooperative Planungsprozesse im Konstruktiven Ingenieurbau. Springer, 2007: 53-74. (in German)

[8] Hildebrandt G. A service oriented, collaborative working environment for the support of modeling processes in distributed civil- and hydro-engineering projects [Dissertation]. Institute for Bauinformatik, BTU Cottbus, Germany, 2006. (in German)