Management of large construction projects and risk minimization by web-based software technology

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ABSTRACT: A web-based software is presented which effectively supports the management of geotechnical construction projects and minimizes risks of execution stages. The software is developed and implemented as client-server application in the model-view-controller (MVC) framework of software architecture and it runs without installation procedure in any web browser. Main parts are a graphical user interface for easy administration and user access, a SQL database for storage of all information and a diagram editor to visualize monitoring results. Software development and implementation concerned also user-friendly handling, security aspects, rapid data access and adaptivity during a running project. The paper describes the basic ideas and main features of the developed software in detail and outlines a practical application.

Keywords: Web-based software, monitoring, information management, risk minimization

1 INTRODUCTION

Planning and execution of geotechnical structures, like tunnels, deep excavations and foundations, are mainly influenced by the fact that they are always prototypes, which makes the essential difference compared to industrial production processes. Geotechnical structures are particularly subjected by the variation of the natural boundary conditions, i.e. the ground and groundwater conditions which are crucial factors for planning and design. In addition to that all other boundary conditions, such as nearby existing buildings, also have to be considered in the design process.

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. That kind of procedure can lead to exceptional situations up to disasters, because of limited information or suddenly changing ground conditions. Concepts and methods to prevent geotechnical hazards and to minimize risks are therefore necessary.

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

Therefore 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. That system must support on the one hand regular construction cycles and on the other hand the dealing with exceptional situations which could occur during execution stages of geotechnical engineering projects. 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. That links to the very important information from monitoring in the frame of the observational method in geotechnical engineering.

The analysis of the above mentioned requirements lead to the idea and development of a web-based software which effectively supports the management of geotechnical construction projects and minimizes risks of execution stages.

2 SOFTWARE DEVELOPMENT

2.1 *Software design framework*

The new software was designed using the Model-View-Controller (MVC) framework. The MVC framework allows especially web-based applications to conveniently separate the software into three main parts: the modeling of the domain (Model), the presentation (View), and the actions (Controller) based on user input (Burbeck 1992).

The model manages the behavior and data of the application domain, responds to requests for information about its state (usually from the view), and responds to instructions to change state (usually from the controller). The view manages the display of information. The controller interprets the inputs from the user, informing the model and/or the view to change as appropriate.
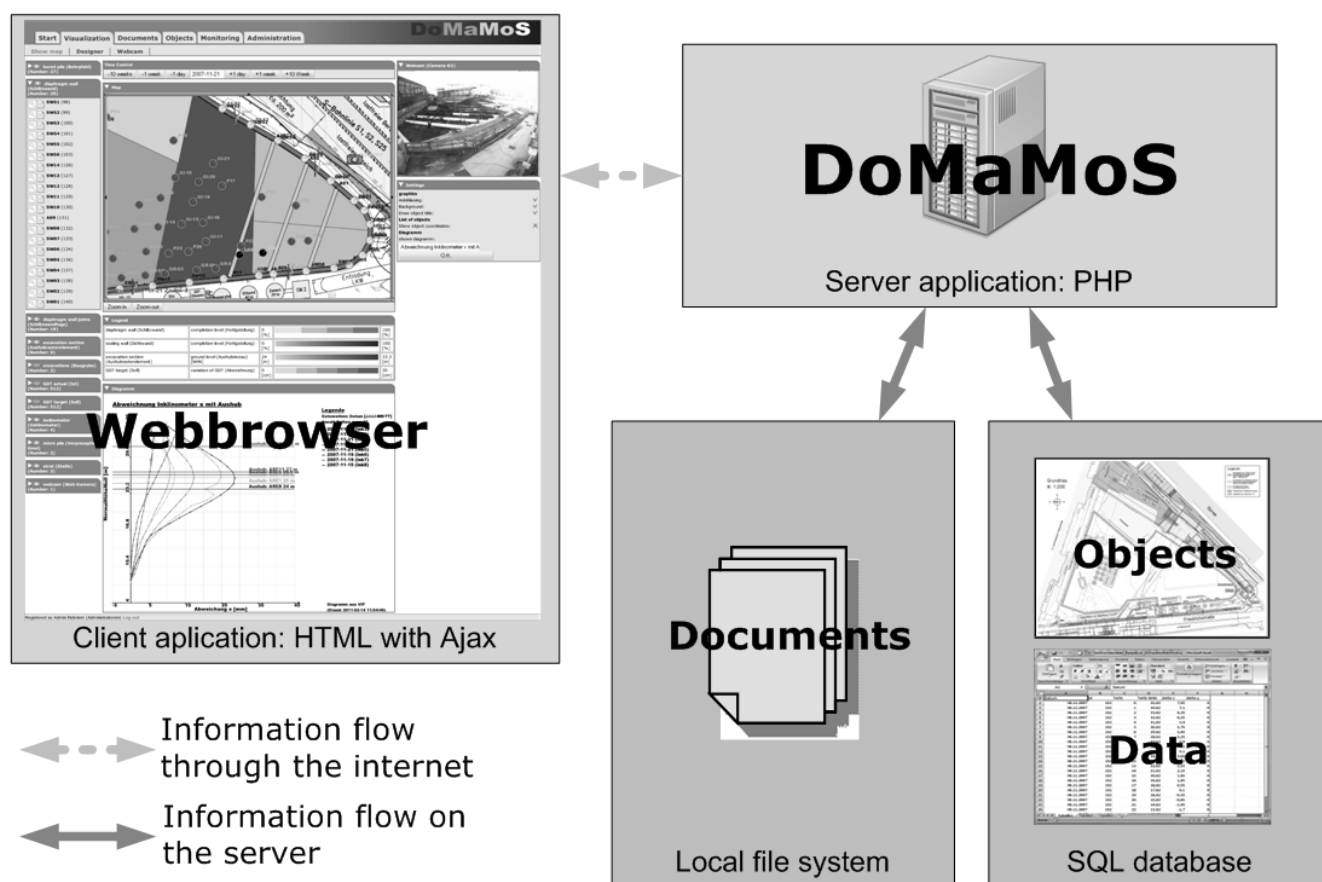

Figure 1. Software design based on the Model-View-Controller (MVC) framework

Figure 1 illustrates the software design in the MVC framework. The SQL database with data and objects as well as the local file system with documents are the model components, the web browser with the client application is the view part and the DoMaMoS server application implemented in PHP is the controller.

At present the SQL database consists of about 40 data tables representing a typical geotechnical project, such as a deep excavation. The number of tables in the database as well as the maximum number of documents in the local file system are not restricted and depend on the practical application and on the available server hardware. Documents are typically unmodifiable PDF files but can be also any other type of file. Results from measurements are directly stored as data in the tables of the database as it is done with the objects, i.e. parts of the construction like diaphragm wall panels, tie backs, jet grouting columns etc., webcams and sensors of the monitoring system.

The user interacts with the project data only by means of the web browser. The layout of the web-browser application is well-arranged but also changeable by the user. It mainly depends on the project specifications and user requirements. Every data request from the user is controlled by the DoMaMoS application. If the user is changing the project view window by changing the view location or by showing or hiding any objects then just an image with small file size is sent back from the controller application.

The data transfer when using the software is therefore rather minimal and allows also the use of smartphones and personal digital assistants (PDA) as clients. A user request for a document is replied by sending the document file back to the user.

It is also shown in Figure 1 that the user interacts by means of the web browser only with the controller, i.e. the server application, without direct access to the data and objects in the database and to the locally filed documents. That software technology and the use of an encrypted hypertext transfer protocol (HTTPS connection) ensure data safety.

2.2 *Data model, data and user rights management*

The well known Entity-Relationship Model (ERM) was used for the design of the database (Chen 1976). ERM uses a special diagrammatic technique, the Entity-Relationship Diagram (ERD) as a tool for database design. The database was implemented by means of *mySQL*, which is an open source database system using the Structured Query Language (SQL). In the database every entity, such as a document, is linked with a document type, an object, a manufacturer and a user by specific relations.

Data as well as user rights management is very important for each real project. The software allows for detailed handling of data and user rights.
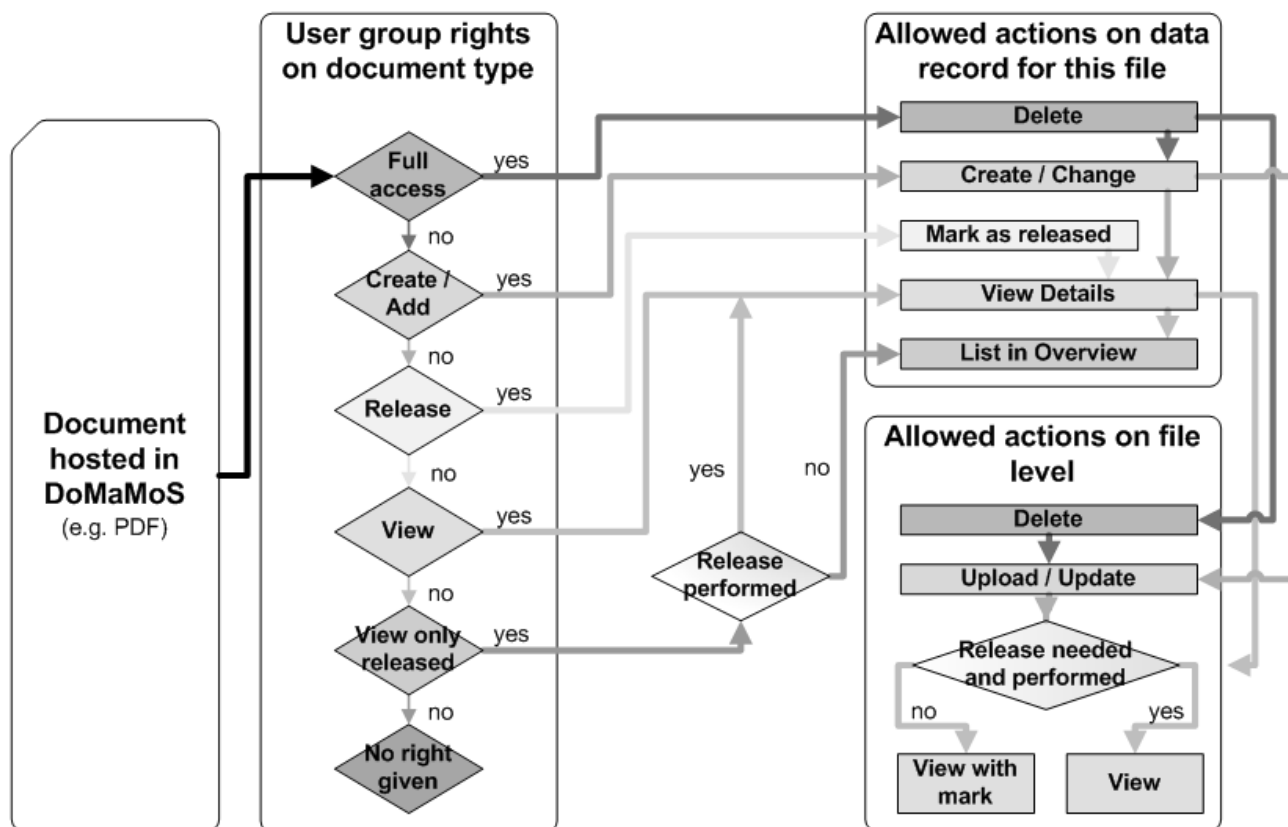

Figure 2. User group rights guideline on documents

Figure 2 illustrates the user group rights guideline on a specific document type. Full access and no access to the documents are the limiting rights, but in between there is any suitable right possible to create. A distinction is made concerning the allowed file actions depending on the given user right. An allowed action on file level regards the file itself on the local file server system whereas an allowed action on the data record regards the database entry for that file.

Each registered user belongs to a user group. Any user request is then checked by DoMaMoS for the given rights on the data, so user without the required rights will not see or get the requested data. The ac-

cess to documents and all other data depends on the rights of the user group in a hierarchical way as shown in Figure 2. E.g. an external geotechnical expert or supervisor may have the right to check and release specific documents or data, which will result in a change of the status of these documents after release. User with the right to see or get only released data cannot see or get the data before the release from the expert. That feature is convenient in any project in geotechnical practice.

3 PRACTICAL APPLICATION

3.1 *Project "Spreedreieck"*

A deep excavation in the city of Berlin was chosen to apply the software platform in a real project. Project "Spreedreieck" was an about 10 m deep excavation with very complicated boundary conditions and a very tight schedule for construction. The excavation was bounded by the railway station building Friedrichstraße in the south, the building Tränenpalast in the west and two railway tunnels in the east and west. The allowable diaphragm wall deformations were strictly limited. A pre-stressed bracing system inside the excavation was installed due to the nearby tunnels and buildings. The deep horizontal sealing base layer was constructed using Gel de Terre (GdT), a newly developed special kind of sodium silicate injection grout material by the company Züblin.

The practical application was successfully done with a previous software version (Mejstrik et al. 2008, Mejstrik & Savidis 2010). That previous software was a pure research prototype version with a number of shortcomings, without client server functionality and no possibility for suitable improvements and extensions.

After the end of the project all data was transferred into the here described completely new developed software. Extensive testing of the new software version was done with these project data and is partially shown in the following subsections.

3.2 *Main web browser view components*

3.2.1 *"Start" tab window*

The content of the web browser window right after login is shown in Figure 3. It consists of the "Start" tab window showing the recently uploaded and/or changed documents and objects since last login. Date and time of the last login is also recorded. The possibility to change the menu entry language between German and English is convenient especially for international projects. The "News" sub tab window can be used as news service.

Figure 3. Web browser view after login

3.2.2 *"Visualization" tab window*

The content of the "Visualization" tab with the "Show map" sub tab window is shown in Figure 4. The "Visualization" tab is the main as well as most convenient interaction point with the user of the platform. It is the core of the graphical user interface. The sub tab "Show map" consists of the main window "Map"

showing a schematic plan view drawing of the construction site with its key information, i.e. construction objects, basic geometries, measurement devices, schedule etc. The diaphragm walls, piles, parts of the bracing system, GdT injection points and the separation of the excavation into two parts can be seen. The main surrounding streets and structures of the construction site are also displayed in the drawing for a quick geographical orientation of the user.

All construction objects are illustrated with their basic geometries, i.e. width, length, diameter, only. Whenever new types of construction objects have to occur in the project, they can be integrated into the model by means of the Project Designer Tool, which can be found with the "Designer" sub tab, but that tool is not shown or described in more detail here.

Two web cams outside the excavation were also installed to report the progress of work in the running project. Pictures were taken and stored automatically into the database. The "Webcam" sub tab gives access to all webcams of the project and all of their taken pictures. The default picture included in the "Show map" sub tab window (Figure 4, top right, "Webcam" window) can be chosen here. Initially the default picture is taken at noon from webcam no. 1.

Below the "Webcam" window there is the "Settings" window enabling the user to set main options directly, e.g. the choice of graphics options.
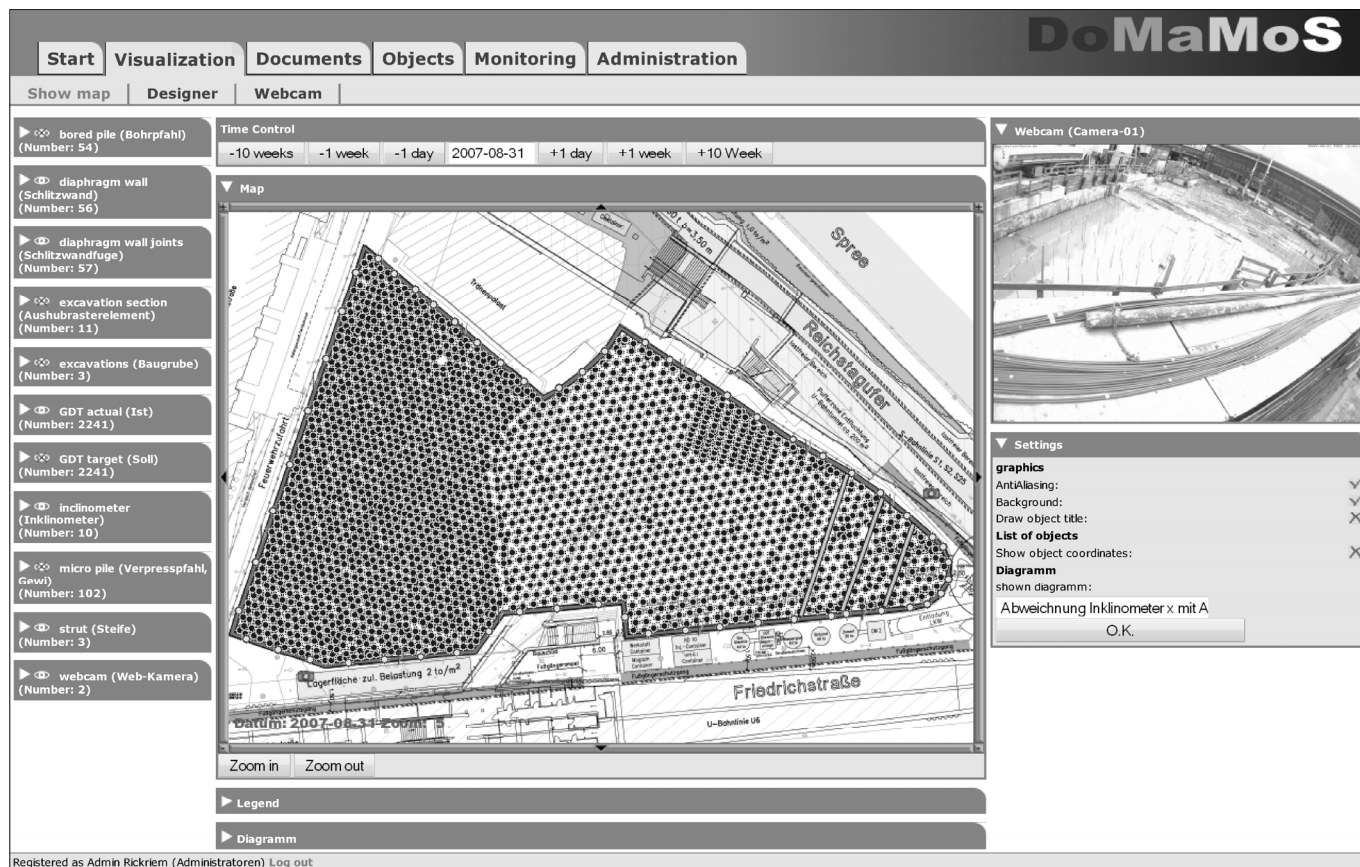
Figure 4. Project windows (most pull down menus reduced) in the web browser view

On the left in Figure 4 there is the object list window, but all pull down menus of the objects are reduced. The window consists of all objects, where the number in brackets is the visible number of objects in the actual main window. Each object type, i.e. bored pile, diaphragm wall panel, diaphragm wall joint, excavation section, excavation, GdT injection point, inclinometer, micro pile, strut and webcam is shown in the object list window.

Above the main project window "Map" there is the "Time control" window visible. It gives the user an easy way to run through the project backwards from the present stage or forward from the past to the present day. The two windows "Legend" and "Diagram" below the "Map" window are reduced in Figure 4.

Figure 5 gives a detailed zoom in view of the northern part of the excavation at a later stage of the project. The legend window is now shown in Figure 5 below the "Map" window. It gives the degree of completion for specific construction objects, such as diaphragm wall panels. Another legend entry represents the ground level inside the excavation pit. For that purpose an irregular grid is drawn overlaid on the excavation plan view. Each grid element is called an excavation section. Different colors mark different depths in the excavation sections.

The "Diagram" window with results from wall inclinometer measurements is shown below the legend window. The user can freely define the layout of the diagram by means of a diagram editor tool, which can be found in the "Monitoring" tab but is not shown here. The diagram in Figure 5 presents not only the horizontal wall displacements but also the corresponding excavation level next to the inclinometer, by a horizontal line. The consistency of all information for the given date in the time control window can be checked by comparison with the webcam picture.

Figure 5. Project windows (most pull down menus open) in the web browser view

The diaphragm wall panel SW 53 is highlighted with dark grey background in the object list window (Figure 5 left) and the details of that panel are given in the "Object - Details" window (Figure 5 right).
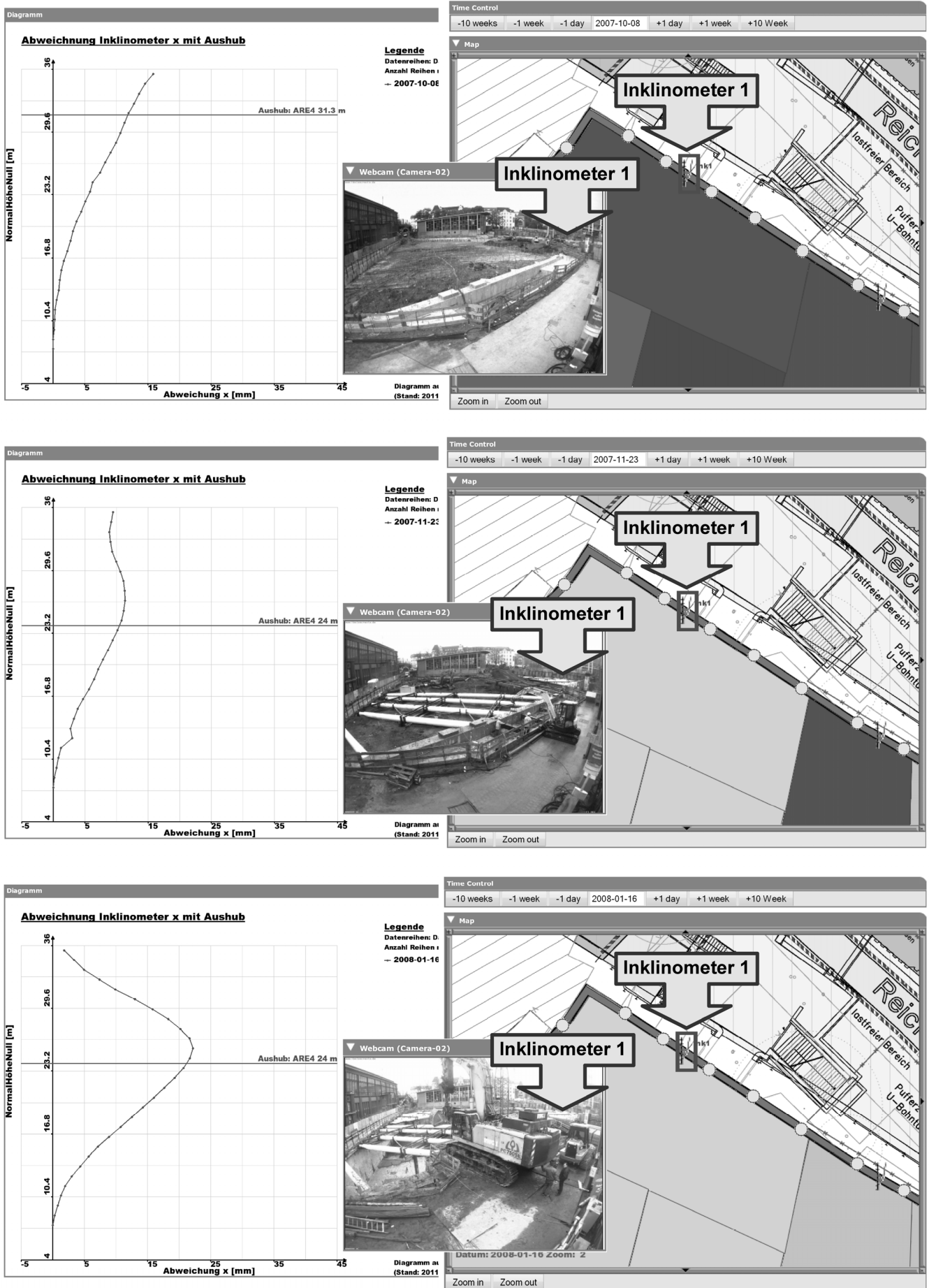
Figure 6. Different completion levels of the excavation

Figure 6 illustrates a partial view of the excavation in the "Map" window with diaphragm wall inclinometer no. 1 at three different days in chronological order from top to bottom, which is seen in the associated "Time Control" windows. The measured wall displacements from the inclinometer are given in the diagram to the right of each "Map" window. The corresponding excavation level next to the inclinometer is drawn by a horizontal line in the diagram. The change of the colors of the excavation sections from top to down in the "Map" windows in Figure 6 is associated with the ongoing excavation works. In the middle is overlaid the picture of webcam no. 2 at noon of each day and also showing the location of the inclinometer. The webcam pictures can be used to check the consistency of all other data.

The presented sequence in Figure 6 gives an outline of the capability of the time control window associated with the visualized project data which can be easily used to check the actual state of the project and to minimize geotechnical risks by efficient management of the available key information.

4 CONCLUSIONS

The purpose of the presented web-based software platform is the support of the daily work of geotechnical engineers. The software is designed to be used for quality management and risk minimization. It can be used independently in time and place by different people working together in the same project. Changing boundary conditions and requirements by clients and contractors require a flexible software architecture, which was recognized during the development stage.

To assess a specific situation on a construction site, only key information is important at first. The controller application and the database map this key information. The web browser user interface presents that key information in an appropriate way which makes it possible for the user to get a quick view of the project's main construction progress and data. All other detailed data can be easily found in the project database.

During practical application of the previous software version it was very well accepted by the construction site management and involved user. After a short time of practice, all participants were able to use the web-based platform in their daily work mainly due to the intuitive usability of the software. The illustration of key information in plain view layout gives a quick overview of the interaction of different types of information in different construction phases. The design of the web-based software in general and the integrated tools have been proved adequate for daily work in a geotechnical project. In a next step the new developed software also has to be tested in practice.

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