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# A New International Database on Case Histories of Monitored Construction of Tunnels and Deep Excavations

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# A NEW INTERNATIONAL DATABASE ON CASE HISTORIES OF MONITORED CONSTRUCTION OF TUNNELS AND DEEP EXCAVATIONS

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ABSTRACT

The prototype of a new database for case histories of monitored construction of tunnels and deep excavations is presented in this paper. The basic requirements for this database have been established by the members of the Technical Committee TC28 of the International Society for Soil Mechanics and Geotechnical Engineering. It is based on the Content Management System (CMS) Typo3. The resulting structure is flexible, the data being mirrored on sites managed by each participant providing data. It uses a web interface where the user can navigate and access to the data via an indexed search engine. Some very basic and brief standard forms describe the type of work, the geotechnical context and the data available. The monitoring data are organized according to formats chosen by each of the participants. Guidelines and minimal rules have also been proposed in order to ensure that the data can be actually used. Nevertheless, the rules concerning availability/accessibility of the data outside the TC28 partners involved in the creation of the database still need to be discussed

## INTRODUCTION

The worldwide needs for urban development and the lack of space at ground level induces an increasing use of underground space for parking lots, tunnels, sewer systems, … These constructions are getting more and more complex and are build in soils of poor geotechnical characteristics and close to existing buildings or other underground structures. The design of such new constructions requires from the geotechnical engineers powerful and reliable tools to simulate in particular the interactions between the new construction and its environment (Breysse et al. 2003, Kastner et al. 2003).

With the development of numerical computational tools, one can find in the literature many publications concerning the simulation of underground works and their effect on the surrounding ground and nearby buildings and facilities (see for example the Proceedings of the 5$^{th}$ Int. Conference on Geotechnical Aspects of Underground Construction in Soft Ground in Amsterdam, Bakker et al. 2005). However, even if numerical tools are becoming increasingly powerful, it seems that concerning in particular displacements and induced deformations, there is no strong correlation between the complexity of the simulation methods used and the quality of the forecast behaviour. To assess the effectiveness of a simulation approach, one often lacks complete and precise field and experimental data, to allow a critical evaluation of the numerical or empirical prediction. This is unfortunate as often, on many tunneling or excavation sites, different parameters are monitored during the works, the monitoring sometimes even being carried out within the framework of research programs. On some of these monitored sites, the data obtained are complete and precise, and certainly of interest to those who have to do similar works or who are working on simulation approaches.

In this context, one of the objectives of the Technical Committee TC28 of the International Society for Soil Mechanics and Geotechnical Engineering on "Underground Construction in Soft Ground" is to share comprehensive field and experimental data, and to make them available to the geotechnical community so that they can be exploited.

This could be done via a database. This idea, raised and discussed during the last TC28 meeting in Amsterdam (2005), although attractive, requires to consider potential difficulties which should be examined carefully, to make sure that the database is effective (public dissemination of the data: ownership of the data, problems related to publications; organization of the data; creation of the database; maintenance of the database and its permanence).

Based on these considerations and in close relation with the TC28 members, the Geotechnical research team of LGCIE – INSA Lyon has build in association with the LIRIS – INSA Lyon the framework for a new database concerning:

- tunneling or deep excavation works with comprehensive monitoring;
- tunneling or deep excavation works facing geotechnical problems (e.g. excessive settlements, failure, damage to nearby structures).

A first prototype of this database is presented in this paper as well as future developments either from the geotechnical side

(TC28 members) or the computer sciences point of view (LIRIS – INSA Lyon).

## TECHNICAL COMMITTEE 28 OF ISSMGE

The ISSMGE has approximately 25 technical committees dealing with specific subject areas in the field of geotechnical engineering (www.issmge.org). These committees provide a forum for discussing, developing and applying specialist geotechnical knowledge. The main purposes of a technical committee are:
- to gather, discuss and appraise current research findings and practices in the TC's subject area,
- to promote dialogue among and between researchers and practitioners,
- to collate information gathered in a form that can be used by the geotechnical professional, and
- to disseminate this information to the membership of the ISSMGE.

In this general framework, the terms of reference of the Technical Committee 28 on "Underground Construction in Soft Ground" are as follows (2005-2009 updated in Sept. 2007):
- to continue providing a forum for interchange of ideas and discussion using representatives from many countries with active interest in tunneling and deep excavations.
- to continue providing a data source of information concerning the design, construction and analysis of deep excavations and tunnels with particular emphasis on the development, effects and control of ground movements and mitigation measures.
- to encourage the publication of well documented case histories and reports on the design and monitoring of deep excavations and tunnels by ISSMGE Member Societies; and to disseminate and discuss these matters at international symposia on Geotechnical Aspects of Underground Construction in Soft Ground.
- to make contact with other Technical Committees and encourage the participation in TC28 of members of these TCs such as TC37 (Interactive geotechnical design), TC2 (Physical modeling).
- to continue the interaction with societies promoting trenchless technology and encourage their participation in the TC28 events.
- to report on the outcomes and other activities at the International Conference on Soil Mechanics and Geotechnical Engineering, Alexandria 2009.

In particular, TC28 organizes every 3 years an International Conference on Geotechnical Aspects of Underground Construction in Soft Ground (Shanghai in April 2008, Amsterdam 2005, Toulouse 2002, Tokyo 1999, London 1996, New Delhi 1994).

## AIMS OF THE DATABASE AND RELATED PROBLEMS

In this context, one of the objectives of TC28 is to share via a general database comprehensive field and experimental data, and to make them available to the geotechnical community so that they can be exploited. This idea, raised and discussed by some participants during the TC28 meeting in Amsterdam (2005), is attractive but there are a certain number of potential difficulties which should be examined carefully, to make sure that such a database is effective.
Previous examples of geotechnical databases have shown these difficulties:
- the rigid framework of the database developed by the French Society for Trenchless Technologies very rapidly discourage the numerous potential users,
- for the same reasons, data collected in MOMIS (Mestat et al. 2005) covering a larger scope of geotechnical constructions (backfill, foundations, …) appear incomplete for using them as a reference for the validation of refined numerical simulation tools and procedures,
- finally the database developed by Moorman (2004) for deep excavations, which appeared to contain comprehensive and interesting data, is actually not accessible.

For all these examples, the structure of the database is rigid, it is managed only on one site. It discourages people willing to share some of their data. Indeed the data and documents had to be reformatted in order to be shared, needing a considerable extra effort without providing immediate positive feedback or benefits. As the above mentioned systems ran and were maintained usually by a small team or one person, they usually disappeared when the person who created the database retires or changes his activity, company or research topic.

These unfortunate experiences have led the TC28 members to propose the creation of a database:
- with a soft and flexible structure,
- that could be shared on several sites and locations,
- enabling the easy and quick introduction of new data with large file sizes and with no required format,
- even for people who are not familiar with databases and without a long training.

## THE CONTENT MANAGEMENT SYSTEM

To fulfill the defined objectives of the database, it has been decided to base its development on a Content Management System (CMS). The CMS are design and dynamic update frameworks for web sites.
An ideal CMS must have certain functionalities:

- User management.
- Workflow and docflow management. It should enable several users to work on the construction of the web site. Therefore, different functions of the publication chain are introduced on the contents (workflow), such as: submit, read, approve and authorize the publication. The information can undergo operations like edition, duplication or deletion. A control of versions allows to roll-back these operations, if necessary.
- The contents of the documents are structured according to the type of use (forum, blog, etc…).
- The CMS allows a complete separation of the content and of its presentation.
- It contains presentation engines.

- It should be easy to develop modules adding new functionalities in the CMS, like personalization of the pages and trace of the users.

Currently, in the open source world, a lot of CMS exists having more or less the characteristics of the ideal CMS. We can quickly describe some of them:
- Joomla is based on the PHP language and the database MySQL is rather for general-purpose with the large amount of modules. Its interface of administration is very ergonomic.
- Drupal (PHP/MySQL) is as a multi-fonction pocket knife which can take the shape of the tool that one wishes to carry out (wiki, weblog, etc…).
- Plone (Zope platform and Python language) is a very complete, professional platform with a simple user interface.
- Typo3 (PHP/MySQL) is a very rich CMS, multilingual, multi site and rather complete in its functionalities.

These CMS are more or less directed for a type of application but they remain rather general.

The choice of the CMS is delicate because a bad choice can lead to the failure of the whole project. It is necessary to define the good selection criteria of the CMS in order to correctly adapt it to the desired application. Among the selection criteria of the CMS, we can mention:

- the adequacy of the software embedded functionalities and the user specifications,
- the user-friendliness of the interface,
- the management of the multilingualism,
- the dynamics of the project and its durability,
- the available functionalities,
- modularity and extendibility,
- etc…

The CMS allows defining modules to personalize them. In the case of the TC28 database application, it is necessary to define several types of data, modules to treat them and templates of presentation for these data. The adaptation of the CMS has a cost and takes time. This point should also be taken into account.

Many of the available open source CMS do not have a user management complete and granular enough to precisely manage the access to the data. Moreover, there is not always a system to trace the users. These weaknesses of management can cause obvious problems of security.

From a semantics point of view, the open source CMS generally do not have adequate search tools: if they have sometimes an index based search engine, they are limited to simple key word base search . An important work should be envisaged if a more powerful search engine in the geotechnical field is required, i.e. if the search should be based on domain specific metadata or if relations between key words has to be integrated. Moreover, in the present international project, the multilingualism is to be taken into account.

Through this rapid state of the art, it can be seen that it is possible to develop a document management system which respects the criteria of an ideal CMS with a degree of personalization suitable to the TC28 requirements and to geotechnical applications.

From all these considerations, it has been decided to use the Typo3 CMS to create the TC28 database.

This software has been chosen for several reasons:
- It uses the popular language PHP and the database MySQL.
- The project community is very active, well documented and a large library of extension modules is available.
- The software is very rich and open enough to enable further development in the future. A particular attention should be paid to the richness of functionalities if the developed application must be very easy to learn for most people, generally not computer specialists. This means sometimes simplify and improve some interfaces.
- Typo3 has a very good user management system.
- It includes a good search and indexing engine (it indexes uploaded document contents for a many different document types : doc, pdf, …).

## GENERAL ORGANIZATION

In order to achieve a flexible, yet reach data structure we propose the general organization of data as illustrated in Fig. 1. It is based on a 5-level definition of the data types.

The central unit is the “project” which is composed of “contracts”. These terms are commonly used and the structure agreed by the different members of the TC28.

The creation of new entries is assisted by the system and users basically have to make a few navigation steps with few choices in order to classify their documents and data to be published and shared.

Once the administrator has created a “Project” page, the user is able to enter data corresponding to this project: For example the laboratory LGCIE has created a project called Toulouse to include the data that have been collected during the research project METROTOUL focused on the works of the Subway line B of Toulouse, France (METROTOUL 2005).

Each “Project” can contain one or more “Contract” attributed to several companies, joint-ventures or association of companies.

Within these contract pages, one or more “Tunnel” and “Excavation” can be created.

For example, the LGCIE has created a “Contract 2” page containing one Tunnel page and two Excavation pages.

Finally in each “Tunnel” or “Excavation” page, “sections” can be included (corresponding for example to precise monitoring sites).

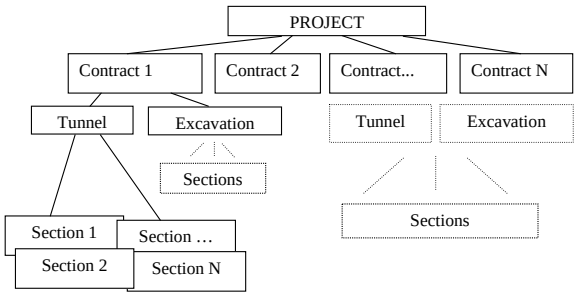


*Fig. 1. General organization of the database*

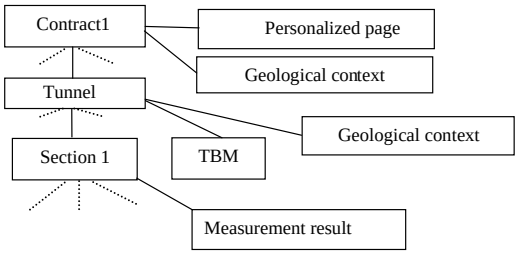


*Fig. 2. Adding leaves to the database tree*

In addition, in each page (Contract, Tunnel, Excavation or Section), other specific elements can be added (Fig. 2):
- Geological context: data about the geological context should be a child of Project, Contract, Tunnel, Excavation and Section.
- Measurement result: data with measurement result can be inserted as geological context in all levels.
- TBM: data about tunnel boring machine should be a child of a Tunnel page.
The structure defined in this section remains general, users don't have to fill in everything, yet have the possibilities to describe also with their keywords the shared documents.

## THE FIRST PROTOTYPE

The TC28 database uses the Typo3 CMS to store data, view and search. The architecture is illustrated in Fig. 3.

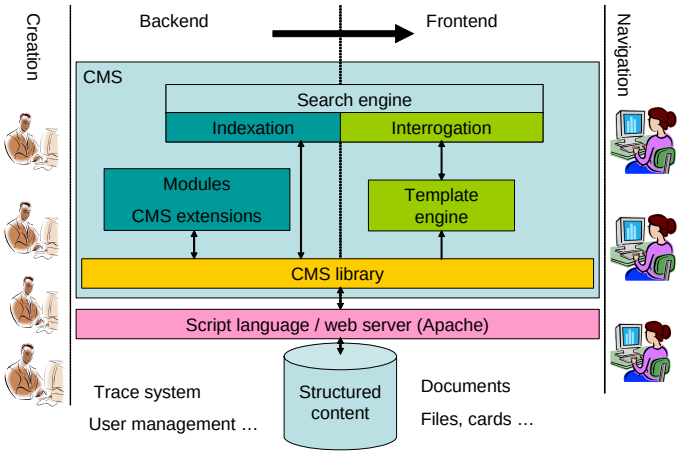


*Fig. 3. Architecture of the system*

This CMS is a page recorder based on a relational database. Typo3 manages pages organized in a tree. Each page can contain objects (text, image, tables or specials object defined specifically for the TC28).
Typo3 is divided into two areas: the backend and the frontend. While the frontend is available for everyone, the backend can be restricted in several levels. The updaters: people who would like to share some data are allowed access to the backend and the administrators for the administration of the website. The backend will always need a username and password. Restricted access to the front-end user can be installed (username and password). This will be used in the future to trace user actions, create user profiles and personalize the user interface.
In the first prototype, we defined eleven new objects. Each of these eleven specific objects to the TC28 database are associated with a simple form containing what has been defined as basic information: the subsequent fields in these objects are either required or optional (Fig.4). Some of these fields are not clearly defined, like the soil classification for example. Further work shall include the complete definition of these fields and the generation of guidelines. Each field has a context sensitive help. This is very useful to see the meaning of the field and how to fill it in correctly.

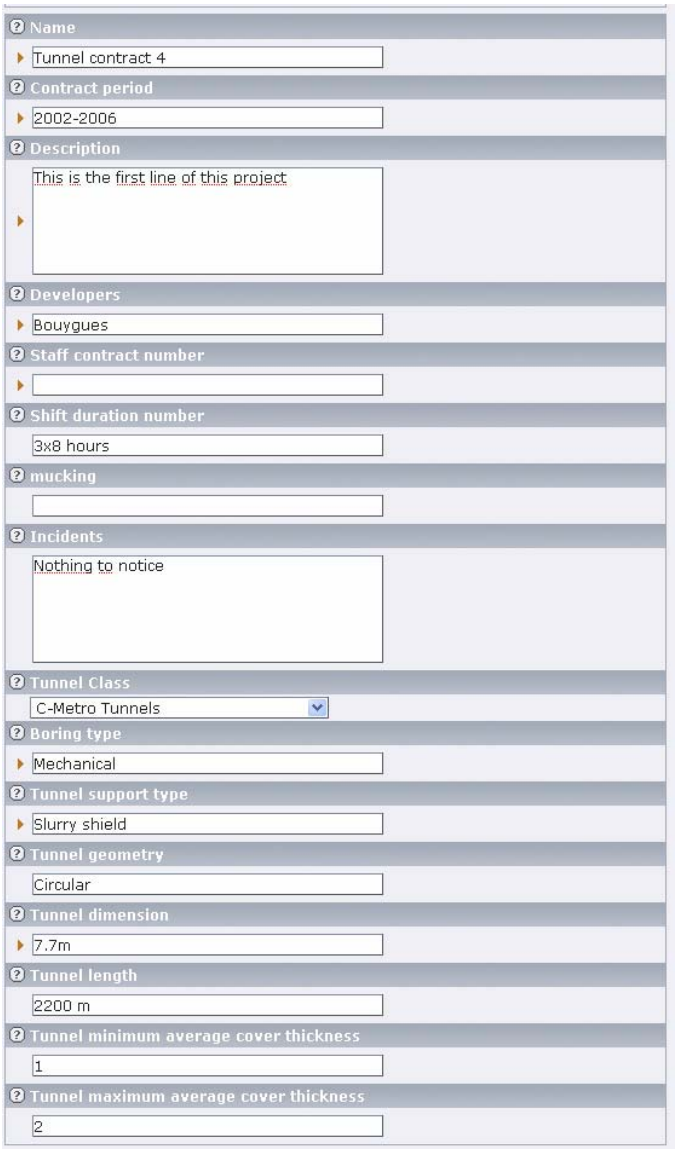


*Fig. 4. Example of a tunnel form (backend)*

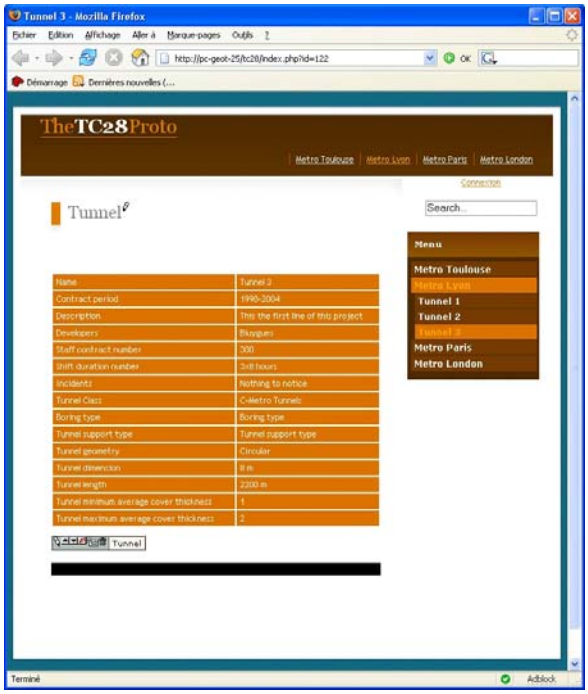


*Fig. 5. Presentation of a tunnel form (frontend)*

Once compiled, these informations are presented at the top of page in a Table (Fig. 5). Furthermore, each page can contain other types of objects, such as standard objects of a webpage for which Typo3 enables an easy and quick creation and management by the back-end user:

- Regular text element: A regular html text element with header and body text fields.
- Text with image: Any number of images wrapped right around a regular text element.
- Images only: Any number of images aligned in columns and rows with a caption.
- Bullet list: A single bullet list.
- Table: A simple table with up to 8 columns
- Special elements (basically used for sharing multimedia documents):
    - Filelinks: Makes a list of files for download.
    - Multimedia: Inserts a media element like a Flash animation, audio file or video clip.
    - Sitemap: Creates a sitemap of the website.
    - Plain HTML: to insert raw HTML code on the page.

    Form elements:
    - Mail form: A mail form allowing website users to ask the data owner to distribute confidential documentations.
- Search form: Draws a search form and the search result if a search is performed.
- Login form: Login/logout form used to password protects pages allowing only authorized website users and groups access.

The CMS software presents a page tree in the backend interface composed of several individual web pages. As far as possible, these physical web pages are coherent with the proposed conceptual TC28 database structure (Figs. 1 and 2). Each page can contain different objects.

Specific access rights can be added to the page tree. A user can see, modify, create, and delete only his/her page tree and its content. The root of a user page tree is a project and the user cannot delete his/her project.

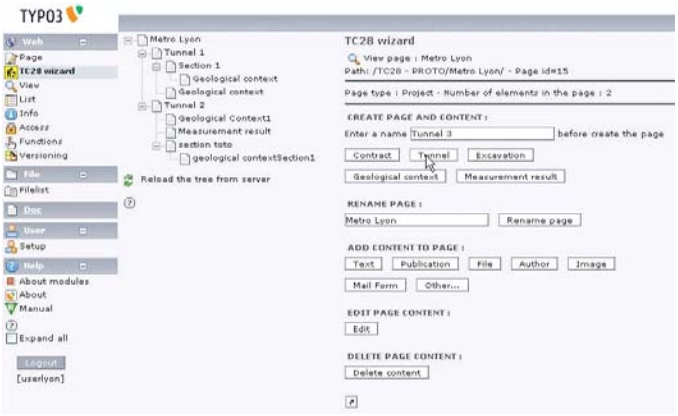


*Fig. 6. The TC28 wizard tool (backend)*

In addition, a specific module interface called “TC28 wizard” (Fig. 6) has been developed. It helps the user to fill faster the database and respect easily the tree structure (Fig. 1). It is a simple and powerful tool to start using Typo3. The interface of the CMS is very rich and the user does not need to learn all the functionalities. The tool makes actions on and in the page, such as creation, deletion, modification, etc…

This tool has been developed in order to present the basic functionalities to fill the database. If the user wants to make a more complex or different data organization; he/she should use the standard Typo3 interface page module.

For the frontend interface, a typical presentation ha been proposed (Fig. 7). This presentation is not unique and can be changed if needed: on the right side of the window, the menu presents all the projects contained in the database (in future developments, only the accessible projects will appears in this menu). The frontend user can navigate and explore the pages of the database.

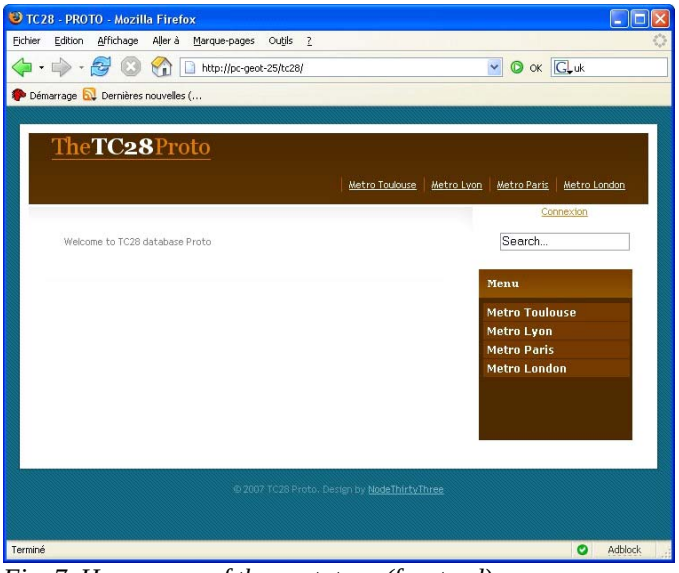


*Fig. 7. Home page of the prototype (frontend)*

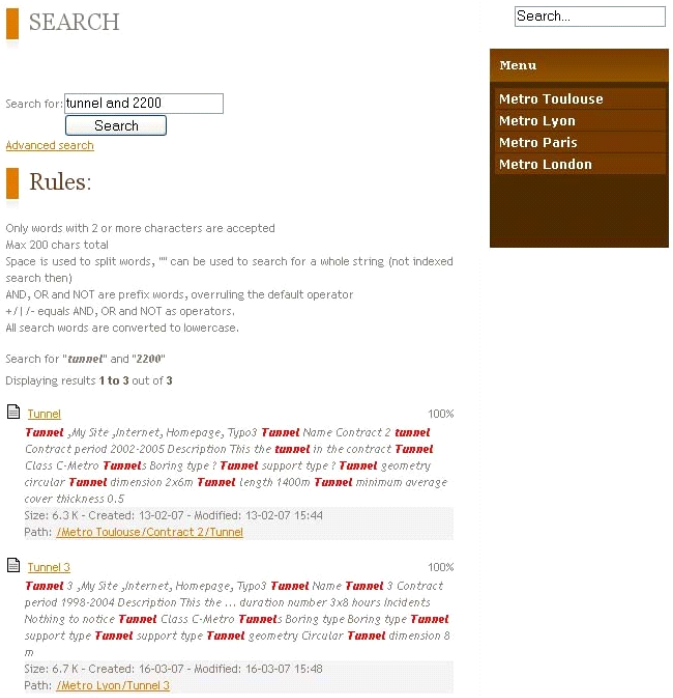


*Fig. 8. The search engine (frontend)*

The standard search engine proposed by Typo3 is illustrated on Fig. 8. This engine is very powerful because the pages and the usual documents (Excel, Word, Acrobat, Open Office etc…) are indexed on regular basis. This feature is very useful because documents could be found and download.

## FEEDBACK OF TC28 AT THE ECSMGE IN MADRID

During the 14th European Conference on Soil Mechanics and Geotechnical Engineering in Madrid (Sept. 2007), a meeting of the TC28 members took place. One of the points on the agenda was a presentation of the prototype of the database and a general discussion on the future development.
The aims of the database were recalled and a live demonstration via the web was performed. The participants agreed on the interest of such a tool based on a flexible framework input system with simple general forms. Some of them accepted to be beta testers for checking the user-friendliness of the tool (both as front-end and back-end users). A first draft of guidelines for the use of TC28 database has been established. The beta testers will give a feedback on both the prototype of database and the guidelines.

Most of the discussion that followed this presentation has been dedicated the issue of ownership and public dissemination of the field or experimental data. Several problems related with the full availability of these data have been raised:
- Problems with ownership of the data: The data generally belong to an organization (e.g. building owner, client, consultant or contractor). These parties can be reluctant to allow free access to the data for various reasons. The principal reason often relates to the problem of claims and litigation which can mark the end of a project involving underground construction. However, once the litigation is complete, it should be possible to obtain the authorization to make the data public. Associated with this, there are sometimes restrictions on data considered to be sensitive by the contractor, because they are related to specific techniques or processes.
- Problem of scientific property rights: This arises when the data have been collected by a research team. Understandably, the team will protect these data until they have been fully exploited in the form of publications. As with the first issue, this restriction should be dropped after a certain time. At this time, making the data available could on the contrary open possibilities for scientific collaboration, the external user often requiring details relating to the data that only those who took the measurements can provide.

Following this discussion, it has been proposed to write a 'charter' that those willing to use the database must sign before being allowed access. The charter would cover issues such as respect of data and its use and publication. This is a key issue that is sometimes abused and can lead to reluctance to submit data for incorporation into a database.

The other question that has been raised is that of how far and/or to what level the data should be disseminated. The participants agreed on allowing first the use of the database to TC28 members, until the different details (technical or related to the 'charter') have been solved. Along the same line, the questions of how good would be the quality and reliability of the data – how to judge/control; should only published data be used; ownership and responsibility of the data; … have been raised but were not discussed.

A last interesting question has not been discussed during this meeting: When an organization or a group of participants has a specific interest in setting up a database, it is generally possible to mobilize enough energy and support, over one or two years, to create the database and begin storing the data. However, experience shows that most database initiatives then collapse very quickly due to lack of long-term support for maintaining the database and collecting data. It should be noted that these databases were all centralized. This experience suggests that a database should be located at several sites (each participant storing her/his data on a personal website), with a general search engine enabling the different data to be accessed. Thus, the withdrawal of a partner would have limited consequences. Each case study could perhaps be duplicated on at least one other partner's website, to limit even more the consequences of withdrawal of some partners from the project. This point should be analyzed in a future meeting of the TC28 members. Until then, the LGCIE will provide this maintenance of the database and store the data on its site. The maintenance is very important and this is a complicated point. We should find solutions in order to maintain it low and have enough services to have something very attractive and improve the life time of the database.

The next meeting of the TC28 members will take place during the 6th International Conference on Geotechnical Aspects of Underground Construction in Soft Ground to be held in

Shanghai (April 10th – 12th 2008). Important issues such as the user "charter" will be discussed.

## FUTURE RESEARCH IN COMPUTERS SCIENCE

One of the major problems with the durability of collective databases is generally the effort that is required to understand the way they work. For example, the structures, keywords or data management habits can be different from one company, city or country to the other. The creation of a common database requires a homogenization of these aspects which in return supposes some time consuming discussion, dialogue, compromise and change of habits.

The laboratory LIRIS works on the management of documents and their annotation and collaborative exploitation (Benel et al. 2001). The collaborative management of documents raises several types of problems:
- problems linked to the annotation of documents,
- problems related to the search and the exploitation of the documents,
- problems of storage and access to the documents.

The specialized scientific document annotation passes by well defined structures on each site. To be able to set up a common interface of document search, it is necessary to make converge the descriptions of various partners. A largely widespread method for the emergence of the consensuses in collaborative description environements is the technique of "Folksonomies" (Gruber, 2005), another is the capitalization and the re-use of the experience (Mille, 1998). These theories have been essentially applied in collective annotation of images (Flikr 2007, Iszlai et al. 2006), videos (Egyed-Zsigmond 2003), or texts in general. According to our knowledge, none of them have been applied to the annotation of technical documents in the field of geotechnical engineering or civil engineering.

Concerning the exploitation of documents (access and navigation), the theories of interface personalization can also be used as well as the assistance in request reformulation based on the case based reasoning (Aamodt et al. 1994). This theory consists in tracing the navigation and search steps carried out by the users and use them to propose new key words to refine a request or propose the query results sorted according to criterias based on the user navigation and search.traces.

## CONCLUSION

The prototype of a new database for case histories of monitored construction of tunnels and deep excavations has been presented. The basic requirements for this database have been established by the TC28 members. Based on the Typo3 sCMS, it has a flexible structure, the data being mirrored on sites managed by each participant providing data. It uses a web interface where the user can navigate and access to the data via an indexed search engine. Some very basic and brief standard forms describe the type of work, the geotechnical context and the data available. The monitoring data are organized according to formats chosen by each of the participants. Guidelines and minimal rules have also been proposed in order to ensure that the data can be actually used. Nevertheless, the rules concerning availability/accessibility of the data outside the TC28 partners involved in the creation of the database still need to be discussed.

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