Rock Mechanics Data: Representation and Standardisation

Proceedings of Specialized Session S02 of the
11th Congress of the International Society for Rock Mechanics

David G. TOLL & Zuyu CHEN

July 12th 2007
Lisbon Congress Centre, Lisbon Portugal

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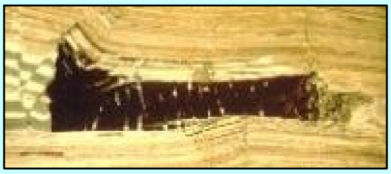

Joint Technical Committee JTC2 on
Representation of Geo-engineering
Data in Electronic Form

and

ISRM Commission on
Case Histories in Rock Engineering

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Specialized Session S02 organised by JTC2[1] *and CCHRE*[2]
*as part of the **11th ISRM Congress***

PAPERS

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[1] JTC2 is a Joint Technical Committee on **Representation of Geo-engineering Data in Electronic Form** of the *International Society for Soil Mechanics and Geotechnical Engineering*, *International Association for Engineering Geology and the Environment* and *International Society for Rock Mechanics* (http://www.dur.ac.uk/geo-engineering/jtc2)

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PROGRAMME

09:00-09:10	Introduction	David Toll, (Chair JTC2) & Zuyu Chen (Chair CCHRE)
09:10-09:30	A rock properties database in XML	John CURRAN, Canada
09:30-09:50	Some new developments on the representation and standardization of rock mechanics data: From the laboratory to the full-scale project	George EXADAKTYLOS, Greece
10:50-10:10	Representing quality and uncertainty for geo-engineering data	Wiebke TEGTMEIER, The Netherlands
10:10-10:30	*Break*	
10:30-10:50	Representing slopes in XML	David TOLL, Singapore/UK
10:50-11:10	A slope classification method by mechanical models and key parameters for case history documentation with XML format	Shihai LI, P.R. China
11:10-11:30	An introduction to the Chinese state database for rock collapse, landslides and debris flows	Yueping YIN, P.R. China
11:30-11:50	Database for landslides and engineered slopes related to China's water resources development based on XML	Zuyu CHEN, P.R. China
11:50-12:30	*Discussion*	

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Some new developments on the representation and standardization of rock mechanics data: From the laboratory to the full scale project

G. Exadaktylos, P. Liolios & G. Barakos
Department of Mineral Resources Engineering, Technical University of Crete, Chania, Greece

ABSTRACT:. An effort has been made to create a Rock Mechanics Database that may be used in the future as a tool for the design of excavations in rocks. This is the reason it was designed to be web-driven through the UCIS platform of TUNCONSTRUCT (Technology Innovation in Underground Construction, http://www.tunconstruct.org/). Its main feature is that it is hierarchical, that is, it starts from the mineralogical-microstructural characterization and reduced raw lab mechanical testing data, then it goes to the data referring to the behavior of the rock in loading and unloading-reloading, as well as to post-peak behavior, separately, after it goes to the identification of elasticity moduli, then to plasticity and damage properties of the rock according to an appropriate constitutive mechanical model, and so on. In order to achieve this for different tests on the same rock - that may be performed by different laboratories - some kind of standardization of procedures is required although not significant departure from established ISRM Standardization Procedures of basic rock mechanics tests is being made. These procedures are discussed here. The next thing to consider is how to upscale the parameters of the intact rock identified from lab testing to the real life scale of the project.

1 INTRODUCTION

Numerical simulation tools assisting the design and construction of underground excavations in rocks employ appropriate rock constitutive models and model parameters. These models may be elastic, elastoplastic (deformational or flow models), elasto-viscoplastic etc. (i.e. Beer & Exadaktylos, 2007). The parameters of the intact rock used in these models are identified from monotonic or cyclic lab tests such as tension, compression, shear, hollow cylinder and so on. Each laboratory uses its own methodology to analyze, store and retrieve this data. The result is that a vast amount of unharmonized data is dispersed throughout Europe – with some of them to be found from the literature or in website (i.e. Hoek's RocLab (RocLab v1.0) for the elasticity and strength parameters of the Hoek and Brown failure criterion according to lithology). It is not uncommon that only a single value of Young's modulus and Poisson's ratio is used even if the rock displays stress-dependant elasticity and anisotropy. In tensile tests the elasticity of the rock is not evaluated even if it is usually significantly different from the elasticity in compression ('unilateral phenomenon'). Furthermore, this rock testing data, are not accessible to other practitioners not involved in the particular project, even if they are concerned with more or less the same rock types tested before.

The aim of this work is to create a *relational rock mechanics database* directly linked in UCIS platform of TUNCONSTRUCT (http://www.tunconstruct.org) that will be continuously upgraded from underground excavation projects. It might be an essential tool in the future for the design of tunnels and other types of underground excavations (e.g. boreholes, caverns etc.). In addition, it would greatly help the *harmonization* and *standardization* of rock mechanics testing by laboratories. The Rock Mechanics Database (RMDB) was written in SQL, and contains standard element mechanical tests on a range of rocks (sedimentary, igneous and metamorphic). Also, an opportunity is open, namely the creation of various useful micromechanical models of "synthetic rocks" and deduction relationships among the various physical, microstructural and mechanical properties of rocks via Data Mining techniques.

2 STRUCTURE OF THE DATABASE

The structure of the database is shown in Fig. A.1 in Appendix A. The steps followed for filling the RMDB were done in close cooperation with Technical University of Graz – Institute for Rock Mechanics and Tunneling (TUG-IRMT) and are the following: a) filling it with the data (templates for keeping common format and terminology have been used), b) finalizing the excel sheets, as well as collecting external photos and microscope photos, c) testing the database to see that it works properly.

A brief description of the basic features and structure of the RMDB has as follows:

- The Database is relational and is written in SQL.
- The RMDB is comprised from 3 distinct interrelated sections, namely: *Rocks Section:* Contains the tables, which are groups of properties and every row inserted is a record of a group of properties, with all the information about the rocks that have been tested, i.e. their origin, microscopy observations, mineral composition, texture and microstructure or fabric, physical properties and photos. *Experiments Section:* In this Section the geometry of the specimens, boundary conditions, measurement techniques (i.e. LVDT's, strain gages etc), basic deformational and strength parameters estimated through the experimental test-ups considered and the

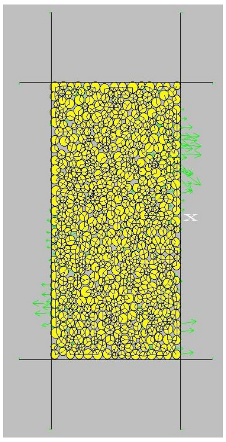
relative data files are contained in respective tables. *Laboratories Section:* This Section contains the tables with all the information for the laboratories that conducted the tests and processed the experimental results. The experiments section is divided into 5 subsections representing the experiment types, i.e. Brazilian Tests (BT), Drilling Tests (DT), Shear Tests (ST), Uniaxial Compression / Triaxial Compression Tests (UCTC) and Uniaxial Tension Tests (UT). The rocks and laboratories sections, as well as each subsection of experiments section, contain several tables from which one table is always the major table (parent table) containing basic information while the others are minor tables containing additional information (children tables). Every row of data inserted into the tables is a record and the rows of the children tables are strictly depended on the rows of their major table. Thus, the database will refuse to store a data row in a child table if there is no major record that is related with this data.

- It relates any rock stored in the database (19 different rock types from Technical University of Crete (TUC) and 10 from TUG-IRMT have been already stored) with all the tests performed by several labs on intact specimens of this rock in tensile, compressive, shear and drilling test conditions.
- It is able to store the local coordinates X,Y,Z of the location of a specimen of a given lithology sampled in a given tunnel project, hence it communicates with other tasks dedicated for the creation of the 'Ground Model'.
- It relates one Lab with many tests etc.
- It may lead to correlations among the rock microstructure with its various mechanical properties.
- Up-to-now the main test types are petrographic observations in optical microscope for assessment of grain size, porosity, mineralogical set-up etc., simple weighting tests, as well as standard tests such as UC, TC, UT, BT, ST and one new non-standard test namely the DT. With regards to the classification of rock types we follow simply the standard petrography, mineralogy and rock mechanics terms respected by the Rock Mechanics Community.

At this stage the data reduction is performed in two levels and stored in the Excel sheets, namely Level-0 and Level-A. In Level-0 where the code number of the test, geometry of the specimen are indicated, the maximum strain, failure strain and failure stress are also shown, as well as the time, force, confining stress, axial and lateral strains are displayed in columns. In Level-A the experimental curve is decomposed into loading and unloading-reloading branches and the elasticity of the rock is evaluated. In a next level, the plasticity of the rock may be subsequently evaluated according to an appropriate yield criterion (e.g. hyperbolic Mohr-Coulomb or other) and Level-A data.

The merits of such a database are the following:

1. The basic feature of this database is that each experiment has been previously properly evaluated and the nonlinear relations of stresses with strains are represented with mathematical functions (polynomials, exponential etc) (*data reduction procedure*). This leads to easy reproduction and retrieval of each test and moreover to generalization to any stress conditions by recourse to TC model (i.e. nonlinear elastoplastic constitutive model).
2. Moreover the RMDB may be exploited for calibration of the micromechanical parameters of discrete element codes such as PFC2D or PFC3D (Itasca a and b) (Fig's 1a, b).
3. Data mining may be performed in a second stage in order to extract useful rules or relationships between the various rock microstructural and physicomechanical parameters, for example relation between Young's modulus with uniaxial compressive strength, porosity, grain size or density etc.
4. Based on item (3) above, preliminary evaluation of basic elasticity and strength parameters in the design phase of an underground excavation project with RMDB may be achieved.
5. One idea is that the RMDB may provide advice on what model/parameters to use depending on the rock type and geological conditions (Beer, pers. Comm.). From the geological model (that specifies rock types, joint networks, major discontinuities etc.) a suggested material model and parameters are automatically determined for each geological region using reduced parameters from the lab test data base (or from lab tests done for the specific project).



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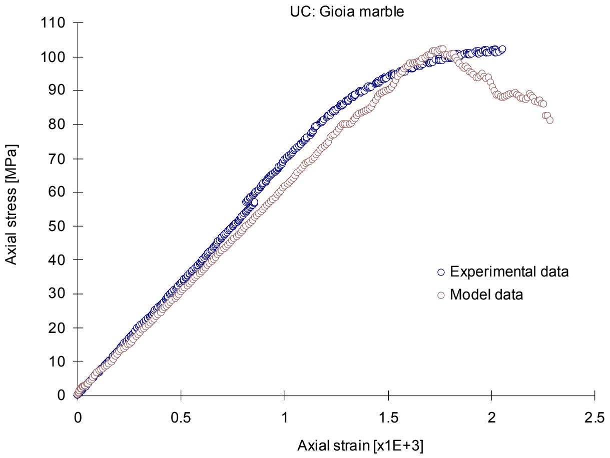


(b)

Figure 1. Calibration of micromechanical parameters of discrete element model for Gioia marble; (a) Particle model of axisymmetric test. Its micromechanical parameters should be identified on experimental data. (b) Example of particle model calibration on experimental data.

3 TEST DATA REDUCTION METHODOLOGY

The databank of TUNCONSTRUCT contains the experimental results of tests in the form of Excel worksheets for each test on each rock type.

In such a worksheet there are two levels of data analysis, namely Level-0 and Level–A. In Level-0 where the code number of the test, geometry of the specimen are indicated, the maximum strain, failure strain and failure stress are also shown, as well as the raw data i.e. time, force, confining stress, axial and lateral strains are displayed in columns. In Level-A the experimental curve is decomposed into loading and unloading-reloading branches and the elasticity of the rock is evaluated. The plasticity of the rock may be subsequently evaluated according to an appropriate yield criterion (i.e. Mohr-Coulomb, nonlinear Mohr-Coulomb, Drucker-Prager etc). The first two levels of data reduction-model calibration of the Uniaxial/Triaxial Compression, Uniaxial Tension and Brazilian tests are explained below.

3.1 *Level 0 and Level A data analysis of UC and TC tests*

For the demonstration of the analysis of UC and TC tests we will use as an example triaxial tests on Gioia mable. The specimens were cylindrical with diameter 38mm and height 78 mm approximately. During the tests the axial force (F), the engineering axial strain (ε_a), and the engineering radial (or lateral) strain (ε_r) were recorded by LVDT's and stored on computer. The axial stress (σ_a) was computed from the formula

$$\sigma_a = \frac{F}{\pi D^2 / 4} \tag{1}$$

Fig. 2 illustrates the primary experimental data obtained from a UC test (the same types of diagrams are also obtained from TC experiments).

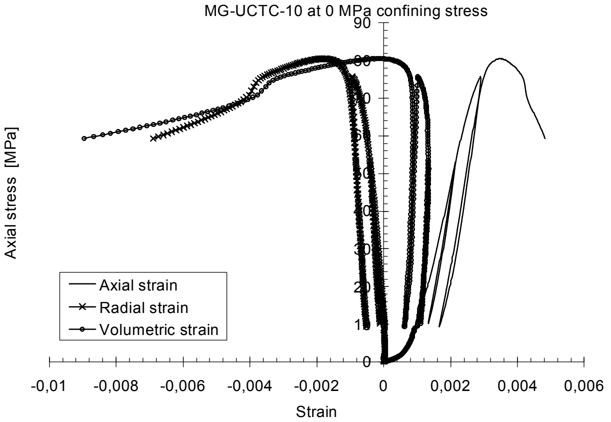


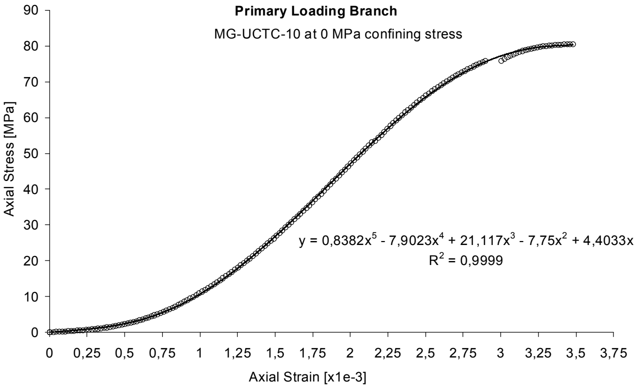
Figure 2. Axial stress vs. axial, radial and volumetric strains for Gioia Marble specimen MG-UCTC-0 at zero confining stress.

In the sequel, the observed mechanical behavior of the marble in Uniaxial Compression (UC) and Triaxial Compression (TC) is described with simple mathematical relations. Note that in this paragraph we deviate momentarily from the assumed stress sign convention and we assume compressive stresses as positive. First, by considering only the loading branch of the UC data, the path of a rock sample to failure can be followed by plotting the measured axial and radial strains versus the applied axial stress. For example the graphs of axial stress vs. axial strain and radial strain vs. axial strain for the uniaxial compression test MG-UCTC-0 are displayed in Figs. 3a and b. The data taken from primary loading loops are fitted by polynomials of the form

$$\begin{aligned} &\sigma_a = a_1 x + a_2 x^2 + a_3 x^3 + ..., \\ &1000 \cdot \varepsilon_r = b_1 x + b_2 x^2 + b_3 x^3 + ..., \\ &x = 1000 \cdot \varepsilon_a \end{aligned} \tag{2}$$

The nonlinearity of marble is manifested by the dependence of the tangent modulus of deformability and lateral strain factor on the applied stress. In fact, differentiating formulae (2) with respect to x or ε_a we obtain the following expression for the tangent moduli

$$\begin{aligned} &E_t = \frac{\partial \sigma_a}{\partial \varepsilon_a} = a_1 + 2a_2 x + 3a_3 x^2 + ..., \\ &\nu_t = -\frac{\partial \varepsilon_r}{\partial \varepsilon_a} = -b_1 - 2b_2 x - 3b_3 x^2 + ... \end{aligned} \tag{3}$$



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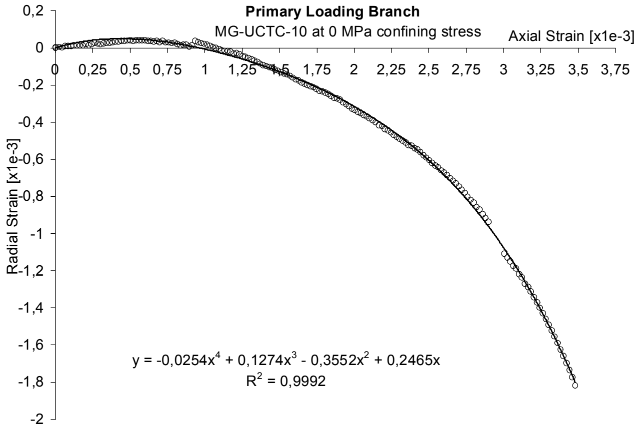
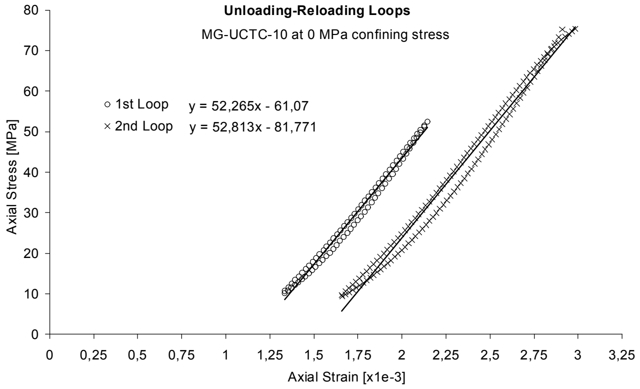


(b)

Figure 3. Loading branches of (a) axial stress- axial strain and (b) radial strain-axial strain curves of Gioia marble specimen MG-UCTC-0 in UC and fitted polynomial curves.

In the case of test MG-UCTC-0 two unloading-reloading cycles were performed before the peak stress at failure in order to infer its elastic properties. From the graphs displayed in Figs. 4 a, b it may be observed that the unloading-reloading curves corresponding to $\sigma_a - \varepsilon_a^{(el)}$ and to $\varepsilon_r^{(el)} - \varepsilon_a^{(el)}$ display hysteresis. Neglecting hysteresis for the sake of simplicity, each of these loops is best-fitted by straight lines.



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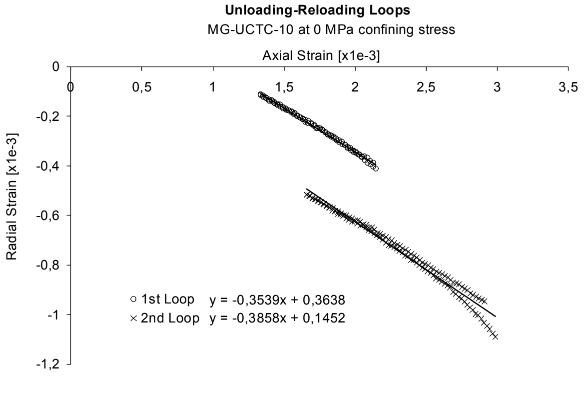
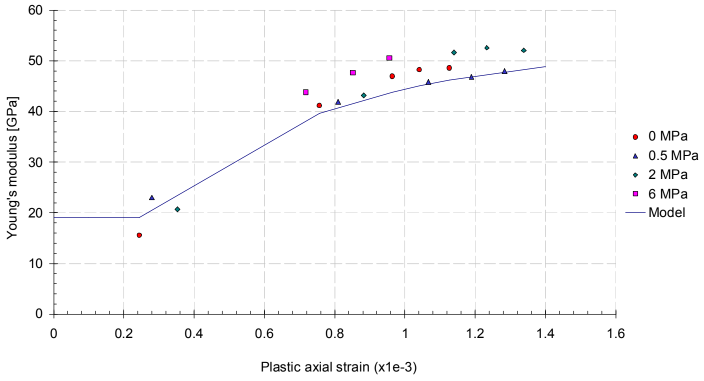


(b)

Figure 4. Unloading-reloading loops for Gioia marble in UC (a) $\sigma_a - \varepsilon_a^{(el)}$, (b) $\varepsilon_r^{(el)} - \varepsilon_a^{(el)}$.

The elasticity moduli are then plotted against plastic axial strain. It should be noticed that in the case of Gioia marble: a) both elasticity moduli seems to be constant relatively to the plastic strain and b) only two unloading-reloading curves are available thus it is not a good example to capture possible non-linear behaviour. In general, in order to plot the elastic parameters against the plastic strain in the pre-peak regime, at least three loops are required at small, intermediate and close to the crack damage stress (Martin & Chandler, 1994). Therefore we will use as an example triaxial tests conducted on Serena sandstone. For this sandstone the dependence of Young's modulus and Poisson's ratio on the plastic axial strain may be easily quantitatively described through simple mathematical models (e.g. Fig's 5a and b):

$$\begin{gathered} E_t = \begin{cases} 16 & 0 \le 1000\cdot\varepsilon_a^{(\mathrm{pl})} < 0.25 \\ 53\left(1-\mathrm{e}^{-\frac{1000\cdot\varepsilon_a^{(\mathrm{pl})}}{0.75}}\right) & 1000\cdot\varepsilon_a^{(\mathrm{pl})} \ge 0.25 \end{cases}, \\ \nu_t = \begin{cases} 0.07 & 0 \le 1000\cdot\varepsilon_a^{(\mathrm{pl})} < 0.25 \\ 0.2193\left(1-\mathrm{e}^{-\frac{1000\cdot\varepsilon_a^{(\mathrm{pl})}}{0.4046}}\right), & 1000\cdot\varepsilon_a^{(\mathrm{pl})} \ge 0.25 \end{cases} \end{gathered} \tag{4}$$



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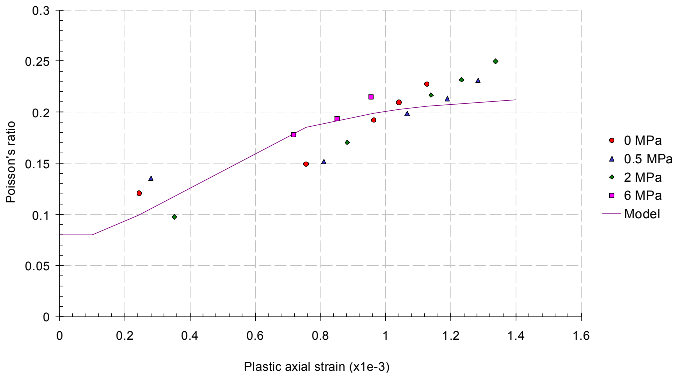


(b)

Figure 5. Dependence of (a) Young's modulus and (b) Poisson's ratio on the plastic axial strain.

3.2 *Level 0 and Level A analysis of UT tests*

We follow the same procedure of the first level of analysis followed for UC and TC tests for the estimation of best fit parameters. For illustration purposed we employ the results from a series of direct tension experiments on cylindrical Lorano marble specimens of height H= 140 mm and diameter of D= 30 mm. Both axial and lateral strains were measured by taking the mean values recorded from four strain-gages attached at specimen mid-height. The input for this analysis is given in terms of stress-strain curves which contain a number of unloading-reloading loops, as shown below in Fig. 6. The axial stress is computed by virtue of relationship (1).

Fig. 7 displays the primary loading curves of Lorano marble in UT. The elastic behaviour of the marble in tension is studied on the unloading-reloading curves for each loop presented in Fig. 8. By fitting straight lines through each loop the variation of Young's modulus and Poisson's ratio may be derived and plotted as a function of the axial plastic strain as it is illustrated in Fig. 9. The following simple two-parameter empirical equations have been found to describe the elastic behaviour of this marble in UT

$$E_t = \frac{1}{1/30.55 + 0.054\sqrt{\left(1000 \cdot \varepsilon_{\mathrm{a}}^{(\mathrm{pl})}\right)}}, \qquad (5)$$

$$\nu_t = \frac{1}{1/0.26 + 6.23\sqrt{\left(1000 \cdot \varepsilon_{\mathrm{a}}^{(\mathrm{pl})}\right)}}$$

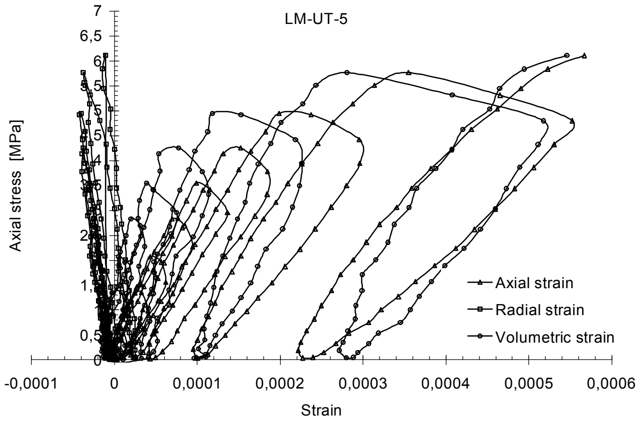
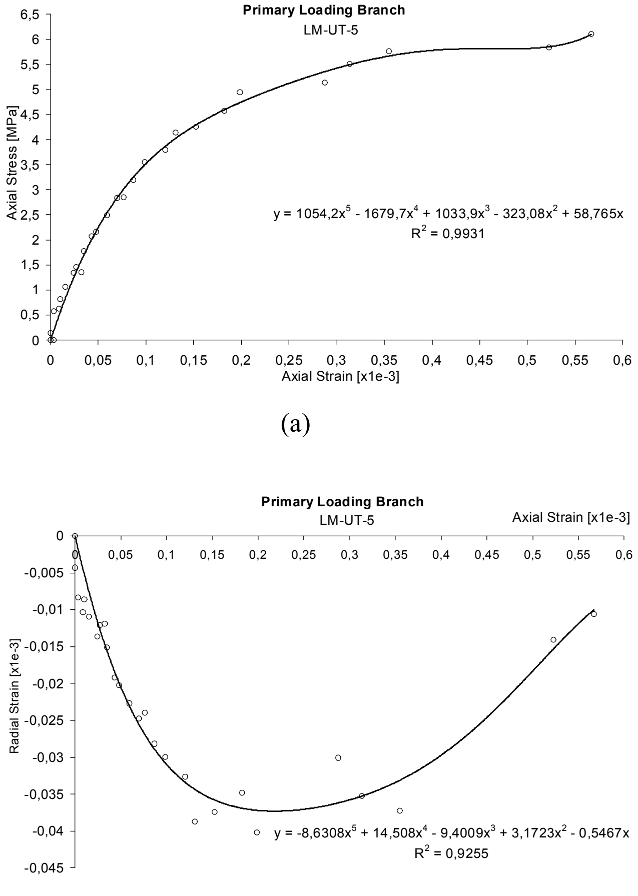


Figure 6. stress vs. axial and radial strains for Lorano Carrara marble specimen LM-UT-5 in UT.



(a)

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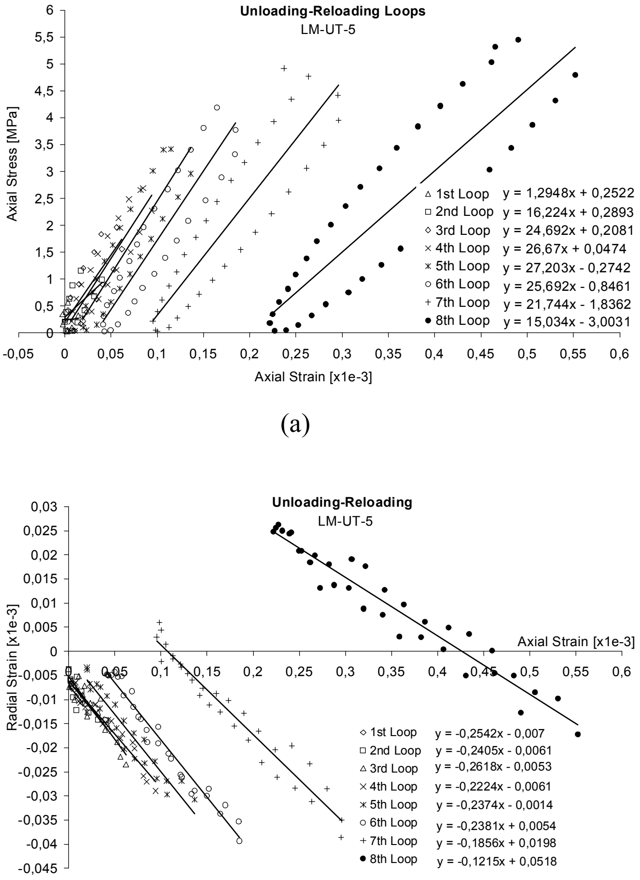
Figure 7: Loading branches of (a) axial stress- axial strain and (b) radial strain-axial strain curves of Lorano marble specimen LM-UT-5 in UT and fitted polynomial curves.



(a)

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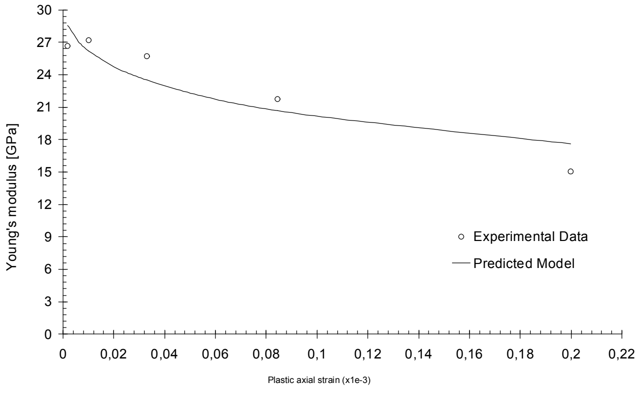
Figure 8: Unloading-reloading loops for Lorano marble in UT (a) $\sigma_a - \varepsilon_a^{(el)}$, (b) $\varepsilon_r^{(el)} - \varepsilon_a^{(el)}$.



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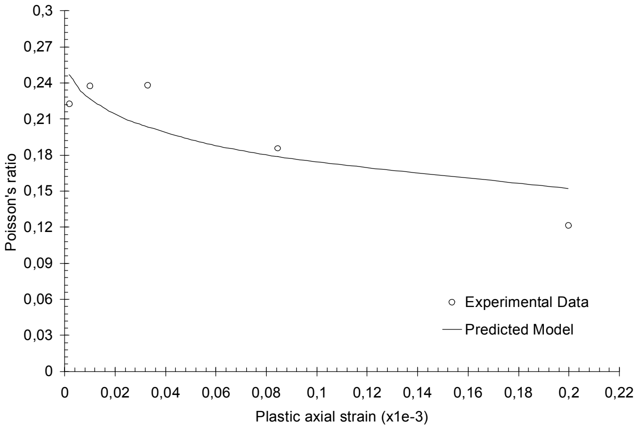


(b)

Figure 9. Degradation of (a) Young's modulus and (b) Poisson's ratio with the evolution of plastic axial strain.

3.3 *Level 0 and Level A analysis of BT tests*

For the analysis of the BT tests we will use as example an experiment that was conducted on Gioia marble. Again as in previous sections we firstly plot the horizontal stress against the axial and lateral strains. The horizontal stress at the centre of the disc is estimated from the isotropic Brazilian formula:

$$\sigma_x = \frac{2F}{\pi D t} \tag{6}$$

where F is the measured axial force and D, t the diameter and thickness of the test specimen. Next, we separate the primary loading branches from the loops and we apply exponential best fit curves on the data as follows (Fig. 10a and b):

$$\begin{aligned} \sigma_x &= \sigma_{tx}\left(1 - \exp\left(-m_{tx}\varepsilon_x\right)\right) \\ \sigma_x &= \sigma_{ty}\left(1 - \exp\left(-m_{ty}\varepsilon_y\right)\right) \end{aligned} \tag{7}$$

where $\sigma_{tx}, m_{tx}, \sigma_{ty}, m_{ty}$ are best-fitted parameters.

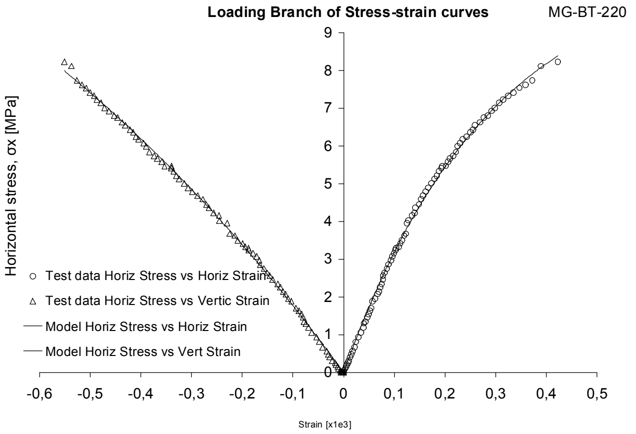


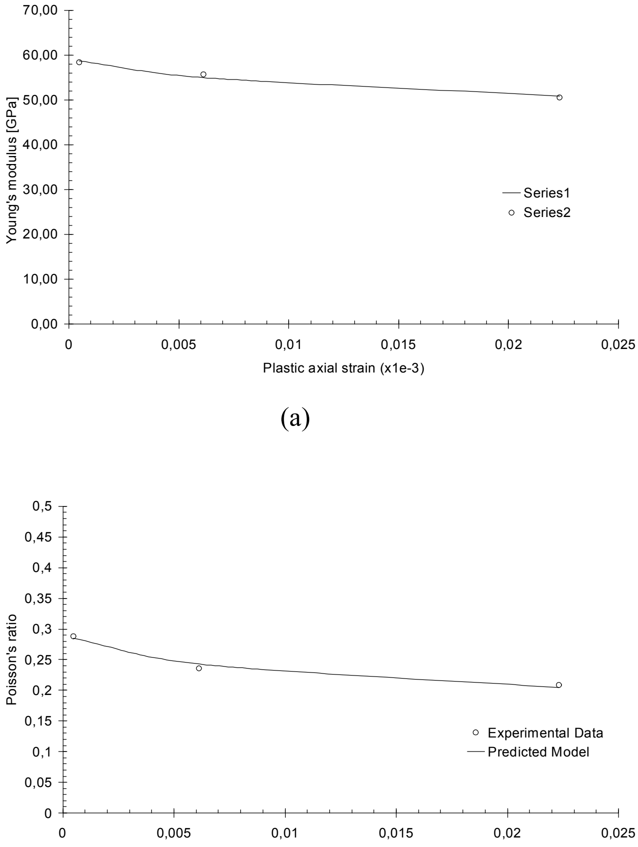
Figure 10. Primary loading branches of horizontal stress-axial strain and horizontal stress - radial strain curves of Gioia marble specimen in BT and fitted exponential curves.

Assuming that the marble is isotropic the tangent deformation modulus and lateral strain factor of the primary loading branch may be calculated by the formulae:

$$E_t = -8\frac{(d\sigma_x / d\varepsilon_x)(d\sigma_x / d\varepsilon_y)}{(d\sigma_x / d\varepsilon_y)+3(d\sigma_x / d\varepsilon_x)} \qquad (8)$$

$$\nu_t = -\frac{(d\sigma_x / d\varepsilon_x)+3(d\sigma_x / d\varepsilon_y)}{(d\sigma_x / d\varepsilon_y)+3(d\sigma_x / d\varepsilon_x)}$$

where the derivatives are calculated easily from formulae (7). It should be noted here that similar formulae for anisotropic rocks are not difficult to be derived. For the unloading-reloading loops the derivatives are simply the slopes of the curves. Then the dependence of the elastic moduli on the lateral plastic strain is described by either formulae (4) or (5) for monotonically increasing or descreasing functions, respectively (i.e. Fig. 11a and b).



(a)

(b)

Figure 11. Deterioration of (a) Young's modulus and (b) Poisson's ratio on the plastic horizontal (lateral) strain of Gioia marble.

4 CONCLUSIONS

In this work we have presented the basic properties of a rock mechanics database and only the basic features of Levels 0 and A of analysis. This database is a first attempt to harmonize rock mechanics data before trying to collect additional data from several laboratories. At this point the database supports only the most commonly used rock mechanics tests; however, in the future it can be enriched with more types of tests. Although not presented here, the database has a web interface through which the data can be easily accessed by any user worldwide.

Apart from the database, a test data reduction methodology was presented regarding the UC, TC, UT and BT tests. The methodology puts on the table a large number of parameters that have to be measured during a typical rock mechanics test, as well as the basic analysis of the data that have been gathered. The manner of the execution of the tests is not insignificant issue. For example, strain measurements during Brazilian or direct tension tests are very important for the understanding of tensile properties of rocks; also, the number of unloading-reloading loops, the type of boundary conditions and post-peak measurements are very important issues that have to be revisited. The benefit of the processed data stored is that they are ready to be used for design of excavations in rocks, for further development at higher levels of analysis, for rock mechanical modelling, as an educational tool etc.

The next issue to be considered is how to upscale the parameters of the intact rock identified from lab testing to the real life scale of the project, by taking into account the size effect exhibited by the intact brittle or quasi-brittle rocks and the effect of joints. This work is under preparation and it will be presented shortly.

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APPENDIX A

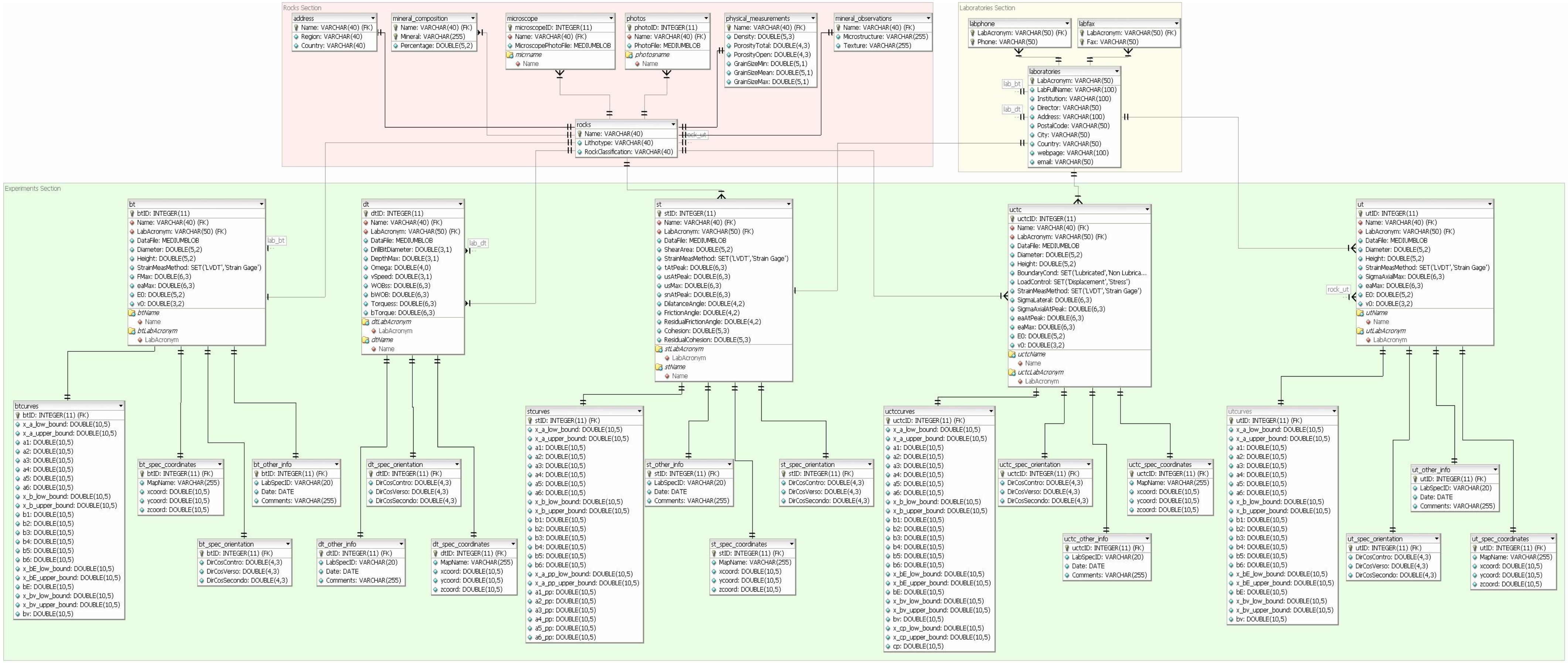

Figure A.1. Relational diagram of the rock mechanics database.

The determination of interpretation uncertainties in subsurface representations

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ABSTRACT:. In geo-engineering re-use of existing data and real world representations is, at present, limited to non-existent. This is mostly due to difficulties regarding the use of data obtained by a number of various professionals. The main problem in this respect is a lack of standardization of data (“lack of data harmonization”) and, underlying, the often-unknown quality of the collected data and derived real world representations. Particularly in geological interpretations, uncertainties are high, since only sparse information is available for the interpretation process. The paper presents a methodology, which will be applied in order to determine the influence of so-called “interpretation uncertainties” on subsurface representations and to develop an appropriate way to include quality and uncertainty expressions in the metadata of the subsurface representation. In addition, an outlook will be given regarding the problem of data harmonization and standardization within the process of infrastructural development.

1 INTRODUCTION

Increasing mobility is of major importance in today’s society. To be able to cover the needs of the world’s citizens concerning their unobstructed movement, sufficient infrastructural capacities (e.g. highways, railways, airports, etc.) in the same way as infrastructure security and transportation safety must be ensured. Clearly, this requires the occupation of a number of specialists, each of them facing different problems, which have to be solved. With it, new civil infrastructures must be planned, designed, and built and existing structures monitored, maintained and eventually be abandoned. These diverse processes are commonly spread over the whole lifecycle of civil infrastructures with a duration of commonly tens of years. The lifecycle can generally be subdivided into six main stages that are namely:

1. Exploration
2. Planning
3. Design
4. Realization
5. Maintenance
6. Abandon

For the execution of the various tasks during infrastructural development, the skills of a number of various professionals (e.g. civil engineers, engineering geologists, GIS technologists, etc.) are needed. Large quantities of geo-information (e.g. GIS-, CAD-, and various other data sets) are collected, generated, (re-) used, managed and exchanged throughout the lifecycle of a civil infrastructure and the main problem as identified today is the difficulty regarding data harmonization; that is the process by which different parties adopt a common (ideally standardized) way of working with geo-information in infrastructural development. The problem of data harmonization is partly caused by the lack of information about qualities and possible uncertainties regarding the collected data as well as derived real world representations. Still, at present, large parts of the data as well as representations are not equipped with quality or uncertainty information. This aggravates the communication and also co-operation between the different parties involved in infrastructural development and intensifies the problems concerning the (re-) use of geo-information as delivered by diverse companies and experts. This missing uncertainty information regarding various types of geo-information and real world representations, and also the use of different types of data structures, geo-information management systems and software packages are, thus, the main obstacles when trying to achieve data harmonization in large infrastructural projects (Figure 1). Consequently, the question is: How can geo-information be harmonized and equipped with uncertainty estimations?

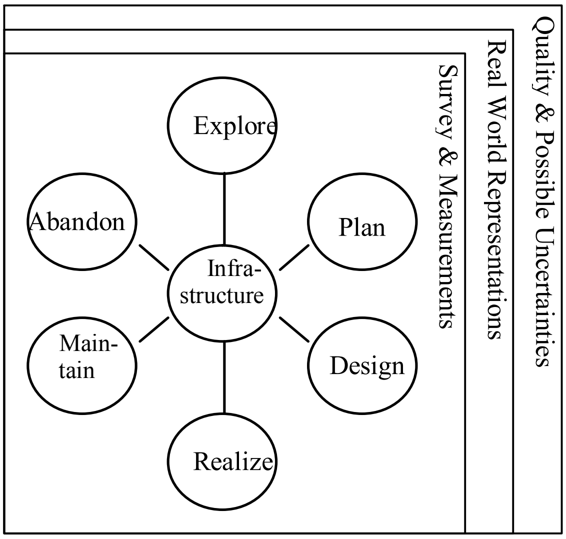

Figure 1. The lifecycle of civil engineering infrastructures.

2 QUALITY AS PART OF THE GEO-INFORMATION

Many people of different professions are involved in infrastructural projects. Regarding the fact that they have to rely on the correctness of the work that is delivered to them by other experts in order to (re-) use this information for further planning and decision making, the quality aspect of geo-information plays an important role in infrastructural development. This makes quality, thus, an important aspect of geo-information and to be able to make successful use of collected data as well as derived representations and interpretations, it is important to receive indications about their quality (Hack 1997, Dilo 2006). Before one can start to determine the quality of the diverse types of geo-information, however, it is important to understand the meaning behind the term “quality”.

Countless definitions can be found in the literature, varying for each profession (e.g. car industry, medicine, education, engineering, etc.) they have been especially defined for. In their pioneering work, Harvey & Green (1993), for example, determined the nature and usage of quality in relation to higher education, where they conclude that quality is often referred to as a relative concept. First, quality is described to be relative to the user of the term and the circumstances in which it is invoked. Then again, regarding higher education, is the “benchmark” relativism of quality, where, on the one hand, quality is to be seen in terms of absolutes and, on the other hand, quality is to be judged in terms of absolute thresholds that have to be exceeded to obtain a quality rating. Following, Harvey & Green suggested that quality should rather be grouped into five discrete but interrelated ways of thinking, rather than being described by only one meaning.

The main definition of quality, however, as used by many engineers and scientists and as defined in various international standards (e.g. ISO 9001:2000) is derived from the meaning of quality as fitness for purpose; that is namely quality as satisfying the determined needs of the user. In these definitions, it is stated: “Quality: The totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs. Not to be mistaken for ‘degree of excellence’ or ‘fitness for use’ that meet only part of the definition.”

Many factors can affect the quality of data and representations and, eventually, lead to imperfections in the data as well as in the resulting work of the various companies. Different kinds of imperfection in data have been defined in the work by Smets (1996). The main aspects are, accordingly, imprecision, inconsistency, and uncertainty. Thereby, imprecision and inconsistency are properties of the data, whereas uncertainty is introduced into the data by attaching weights to the worlds in order to express our opinion about which might be the real world situation.

Since the problem of data and representation quality together with the numerous factors influencing this quality is too complex to be covered all at once, this specific part of the research is focused on uncertainties in geo-information and real world representations concerning the geotechnical (subsurface) part of infrastructural development. This seems to be most appropriate considering the fact that, usually, only sparse information is available for the interpretation as well as representation of the geological situation at the construction site and, thus, the knowledge and experience of the geo-engineers has a significant influence on the final result.

2.1 *The uncertainty aspect of quality in geo-information*

Uncertainty in geo-information plays an important role throughout the development of infrastructural projects, because it can affect the future (re-) use and processing of geo-information, and also, most importantly, the process of decision making in these large projects. Despite the number of initiatives trying to reduce the uncertainty from an end-users and decision-makers perspective, it is, still, not possible to completely eliminate this factor of uncertainty (Foody & Atkinson 2002).

Often, uncertainty is described in rather general terms as “…a measure of the difference between estimation and reality”. This, for example, might be the difference between the thickness and extent of a sand lens as determined via an interpretation of borehole and CPT data as compared to the real world situation; expressed in percentage. A definition similar to this rather general description is used in statistics, where the uncertainty is defined as “the estimated amount or percentage by which an observed or calculated value may differ from the true value”.

In the same way as the quality aspect, uncertainty as part of this quality aspect is determined by different types of uncertainty (Figure 2). These are, for example, uncertainty with regard to spatial prediction, uncertainty resulting from site investigations/ surveys/ measurements, or uncertainties resulting from geological and geotechnical interpretations (i.e. mainly caused by limited amounts of data).

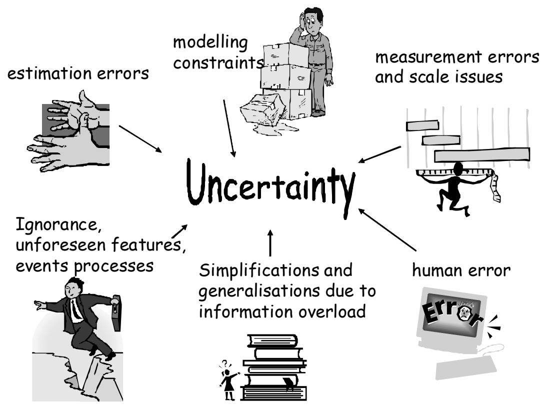

Figure 2. The different types of uncertainties in geo-engineering (Hack et al. 2006).

These days, numerous techniques are available for the determination of uncertainty resulting from the process of spatial prediction. Depending on the quantity and quality of available data, but also on the type of object (i.e. continuous or categorical), for which the uncertainty must be determined, different estimation techniques are frequently used; that are namely geostatistical simulations, kriging and probability-based methods (Orlic 1997, Zhang & Goodchild 2002).

As described by Hack et al. (2006), also in geo-engineering work it is (or should be) common practice to make an estimation of the errors/possible errors in the geotechnical properties of the subsurface and the influence of these errors on the engineering structure to be built in or on it. Different methodologies, such as the "geotechnical base-line methods"(Staveren & Knoeff 2004), probability studies and Monte Carlo simulations (Viseur & Shtuka 1997, Hack 1998, Hack et al. 2003), are applied to give a certain amount of quantification of possible errors in the design of an engineering structure due to uncertainty regarding the subsurface properties. Statistical routines exist, thus, in extenso, to calculate the temporal-spatial distribution of properties in a unit (see also Deutsch & Journal 1998, Houlding 2000).

Next to the uncertainty associated with spatial prediction or the prediction of geotechnical properties, there are, however, mainly two other sources of uncertainty one should constantly be aware of, since these types of uncertainties are less prominent and, thus, difficult to be defined. Due to the scarcity of data, these additional types of uncertainty are most prominent in geo-engineering and, accordingly, in subsurface real world representations. As described by Houlding (1994), these two sources of uncertainty are:

1. The potential for investigation errors (i.e. locational errors or measurement errors caused by wrongly calibrated machines)
2. The potential for interpretations errors (i.e. uncertainty introduced by the expert, depending on the experience and prior knowledge)

Unfortunately, there is little one can do about these specific types of uncertainty in geo-information. To be able to quantify the uncertainties regarding investigation error in sample and observation values, comprehensive research would be necessary into each of the common investigation techniques in use. In the same way, it is rather difficult to determine uncertainties that are caused by errors made during the interpretation of geological features. This is a rather subjective procedure and up till now, there is no way of incorporating it into a computerized approach unless we are prepared to quantify ourselves during the interpretation process.

Thus, numerous estimation techniques for the determination of uncertainties associated with spatial prediction have been developed and are frequently used in practice. However, especially regarding the problem of uncertainties in subsurface real world representations, more research is still to be undertaken and especially the so-called "interpretation uncertainties"; that are uncertainties introduced into the representation by the experts themselves; must be determined and communicated, as they form a dominant source of uncertainty in geo-information.

3 CRITICAL RESEARCH ISSUES AND DEVELOPMENTS

Due to the fact that for the representation of the subsurface (geotechnical) situation at a construction site only sparse information is available, the knowledge and experience of the interpreter plays an important role regarding the outcome of the interpretation. The quality of his experience and "a priori knowledge" that is of major importance for the interpretation process can, however, not be qualified at present. If the engineer/geologist is good, this will result in a good and reliable geotechnical representation. If the engineer/geologist is not as good, it will result in higher uncertainties and, thus, a poor geotechnical representation. Today, many up-to-date analyses are available describing all sorts of uncertainties in measurable properties. Without an indication on the level of interpretation uncertainties to be expected in the representation, it is, however, difficult to rely on any geotechnical representation and to use it for further planning and decision-making.

Therefore, part of the research will be focused on the determination and communication of the so-called "interpretation uncertainties" in subsurface geotechnical representations.

As this problem cannot be completely solved in this limited amount of time, a first step will be made towards an acceptable solution. The goal within this research is to arrive at a description of the level of interpretation uncertainty to be expected in a certain interpretation or representation of subsurface conditions. This level of interpretation uncertainty in geotechnical representations is, at this time, intended to be described on a scale of, for example, 1 to 5; with 1 a low level of interpretation uncertainty and high reliability of the subsurface representation and 5 vice versa. For the determination of the level of interpretation uncertainty, a weighting system will be developed and applied in order to arrive at scalable values indicating the interpretation uncertainties to be expected in a certain geotechnical representation as well as their influence on the construction and maintenance measures as needed for the infrastructural project. Aspects that will be taken into account in the weighting system are, for example, the quantity of the collected data, the quality of the collected data, the extent/size of the construction site, the expected impact of the civil construction on the geology (i.e. type/size/etc. of construction) and the experience of the geotechnical expert executing the interpretation (i.e. familiarity with geology around the construction site, number of representations made in this area, etc.). Each of these aspects will then be given a factor depending on the conditions met in a certain project. Additionally, these factors are weighted depending on their influence on the final interpretation uncertainty to be expected in this geotechnical representation.

In order to get insight in the present use of uncertainty information, it will be co-operated with various engineering companies throughout this research. A number of companies involved in infrastructural development will be visited and questioned about their use of uncertainty information in subsurface real world representations and case studies will be analyzed in order to acquire information about the influence of the expert knowledge on the quality of a real world representation.

Finally, the newly determined uncertainty information will, ideally, be included in the metadata; that is “data about data”, additional information that is used to provide further information to, for example, attribute tables; of the subsurface (geotechnical) representation and, if possible, be equipped with supplementary information regarding the implications of this interpretation on the construction of the infrastructural project.. This should, significantly improve the communication between the companies involved in infrastructural development and facilitate the (re-) use of the geo-information.

4 CONLUSIONS & FUTURE RESEARCH

In addition to the missing information concerning possible uncertainties in real world representations, the numerous types of geo-information as used in infrastructural development, a lack of standardization and, especially, harmonization of the geo-information makes the different working steps in civil engineering projects difficult.

In infrastructural development, a number of different experts are involved in the lifecycle of the civil infrastructure. Thereby, different types of data, file formats, software packages, etc. are used for the representation of the real world. Depending on the specialization, also different representation techniques for the representation of the diverse real world objects are available. During the last years, several initiatives have been followed in order to integrate the various types of geo-information (Oosterom et al. 1994, 2006; Zlatanova et al. 2002). The whole problem of geo-information harmonization is, however, too complex to be solved in a short time. Thus, more work still needs to be done to achieve a solution to this problem.

In order to increase the data harmonization and to improve the communication and co-operation of the different parties involved in infrastructural works, the second part of this research will be focused on the topic of data harmonization; with its main focus on the “meaning of the data” (the thematical semantics of data). With it, it is desirable to use similar semantics for the representation of the various objects. Furthermore, real world representations should be equipped with sufficient metadata describing their meaning and implications for the development of the project in a language understandable by all different parties. Consistent application of terms is thereby a prerequisite for successful implementation and unambiguous adoption of legislation, regulations, guidelines and interpretations.

To achieve this, a glossary shall be established to define the meaning of those terms regarding geographic information that are used regularly within infrastructural projects. Therefore, various (engineering) companies will be visited and, together with information gathered with the help of a questionnaire, information about commonly used semantics, attributes, definitions, standards, etc. gathered. Finally, a concept will be developed for the harmonized use of common semantics together with additional metadata.

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Representing Slopes in XML

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ABSTRACT:. The paper outlines some preliminary proposals for defining an internationally agreed form of data representation for slopes and landslides. This is intended to stimulate discussion that can feed into work by Joint Technical Committee JTC2 on “Representation of Geo-Engineering Data in Electronic Form” in collaboration with JTC1 on “Landslides and Engineered Slopes”. A simple existing scheme is described for using XML (eXtensible Markup Language) for representing slope case histories. Some suggestions are made as to how XML can be used to provide representation at a variety of levels of detail in order to serve the different professional groups who use slope data. The use of GML (Geography Markup language) to define the detailed coordinate level is outlined.

1 INTRODUCTION

The paper addresses current issues of representation of slope and landslide data using XML (eXtensible Markup Language). This is part of a larger initiative to develop standard representation schemes for geo-engineering data. The three international geo-engineering societies (International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE), International Society for Rock Mechanics (ISRM) and International Association for Engineering Geology and the Environment (IAEG)) have formed a Joint Technical Committee, JTC2 (http://www.dur.ac.uk/geo-engineering/jtc2). JTC2 will oversee the development of an internationally agreed form of representation of geo-engineering data that can be used to store such data on the World Wide Web and transfer data between computer systems. This will ensure that geo-engineering data is stored in the same format anywhere on the web.

There are other benefits to having an internationally agreed data standard apart from allowing data to be made available on the World Wide Web. A standard file format can also be used for data exchange between organisations and computer systems. It could also be used for importing or exporting data to or from other software packages such as databases, GIS systems or analysis packages (Toll, 2001). It is hoped that developers of geo-engineering software will see the benefits of reading their data from a standard file format, rather than each software package having its own file format.

This paper does not intend to propose a definitive form of representation for slope data. The intention is to provide some preliminary proposals to stimulate discussion. JTC2 will be working with Joint Technical Committee for Landslides and Engineered Slopes (JTC1) (http://www.geoforum.com/jtc1/) to arrive at an internationally agreed format.

2 EXTENSIBLE MARKUP LANGUAGE

XML allows simple text files to be 'marked up' by including 'tags' within the file. These tags can be recognised by an XML compliant web browser. XML is being widely adopted by web developers for producing the next generation of web-based materials (http://www.w3.org/XML/). XML is a more generic form of mark-up language than HTML (Hyper-Text Markup Language), which has been the main language used on the World Wide Web. HTML is purely a display language that allowed tags to be introduced to define how the text would be formatted for display within a web browser. XML allows the tags to be user defined. This means that the tags can be used to give meaning to the contents of a file; for instance data can be marked up using <slope> ... </slope> tags to indicate that all data between these tags relates to slope information.

The advantage of using XML to represent data on the World Wide Web is that the data (stored in an .xml file) is separated from the formatting information. Formatting is provided by the use of a Stylesheet (.xsl) file. This means that the data can be formatted in different ways for presentation without having to make changes to the data file. This separation between data and formatting instructions is a major advantage compared to HTML where formatting commands are embedded in the data file.

It will be possible to use XML tags in order to search for files on the World Wide Web using XQuery (http://www.w3.org/TR/xquery/). This will make web-based searching much more productive and focused, rather than the keyword searching options that are currently available. However, if different data standards are adopted by different countries, the facility of being able to search easily for data anywhere in the world will be nullified.

3 EXISTING SCHEMES

An internationally agreed format can build on the IAEG suggested methods for reporting landslide data (Working Party on World Landslide Inventory, 1990; 1991; 1994). However, with the development of large datasets in GIS systems and databases it is important to develop more detailed forms of representation and ones that are suitable for electronic storage. The ongoing development of Geography Markup Language (GML) (http://www.opengis.net/gml/) and GeoScience Markup Language (GeoSciML) (http://www.opengis.net/GeoSciML/) can provide the underpinning for such a scheme. This can be supplemented by geo-engineering data. Toll (2007) outlines ongoing developments relating to geo-engineering applications.

Current work is underway to develop representation schemes for landslides, such as work in South America through the Multinational Andean Project: Geosciences for the Andean Community (http://www.pma-map.com/en/gac/). Another initiative underway in Australia is the Landslide Database Interoperability Project (Osuchowski, 2006).

4 A SIMPLE SCHEMA (SLOPESML)

Hatipoglu (2003) developed an XML schema (http://www.ins.itu.edu.tr/bulent/slopesml/) for storing case histories of slope failures. This was a very simple schema for providing generally qualitative descriptions of case histories, with a small number of tags for providing quantitative data (such as length, depth, area and volume of the failed zone). A number of examples based on this initial proposal (modified slightly to allow inclusion of images) can be found at:
http://www.dur.ac.uk/geo-engineering/geotechml/
Slopes/CaseHistoryInventory.xml

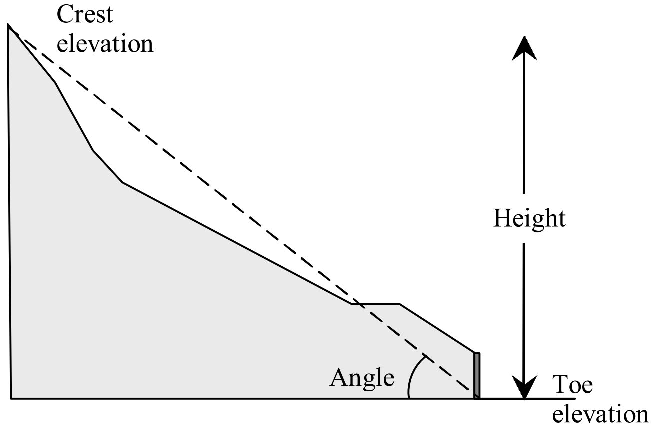
An example of an XML file and an extended version of a style sheet for displaying the case studies can be found at:

XML file: http://www.dur.ac.uk/geo-engineering/geotechml/
Slopes/Vangharad/vangharadcase.xml
XSL file: http://www.dur.ac.uk/geo-engineering/geotechml/
Slopes/SlopeSML.xsl

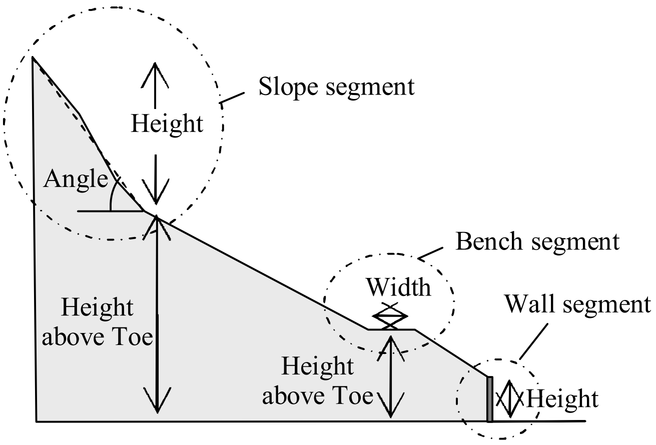
These simple examples are provided in order to illustrate the use of XML but the schema itself is too simple for useful representation.

5 REPRESENTING SLOPES

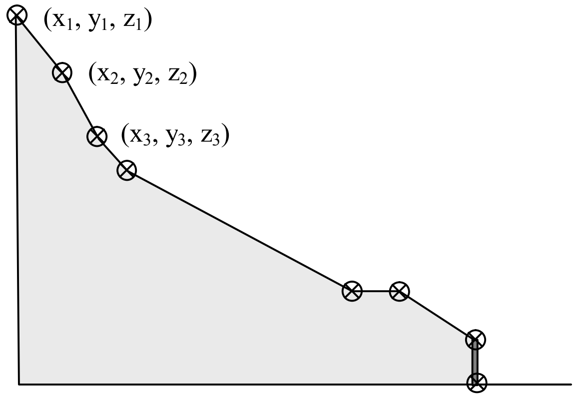
Slope data is used by a range of professionals: geotechnical engineers, geomorphologists, geologists and planners. They may each need to represent information in different ways (Aleotti & Chowdhury, 1999). Even if we consider only topographic information, different levels of representation are likely to be needed. Those dealing with hazard assessment will typically store data on the slope height, slope angle and aspect (as well as lithology and land use) (e.g. Wang & Sassa, 2004). Geomorphologists may want to divide a slope up into segments having different land forms. Geotechnical engineers will usually produce quantitative cross-sections showing detailed topography.



Level 1: Overall Representation



Level 2: Segmental Representation

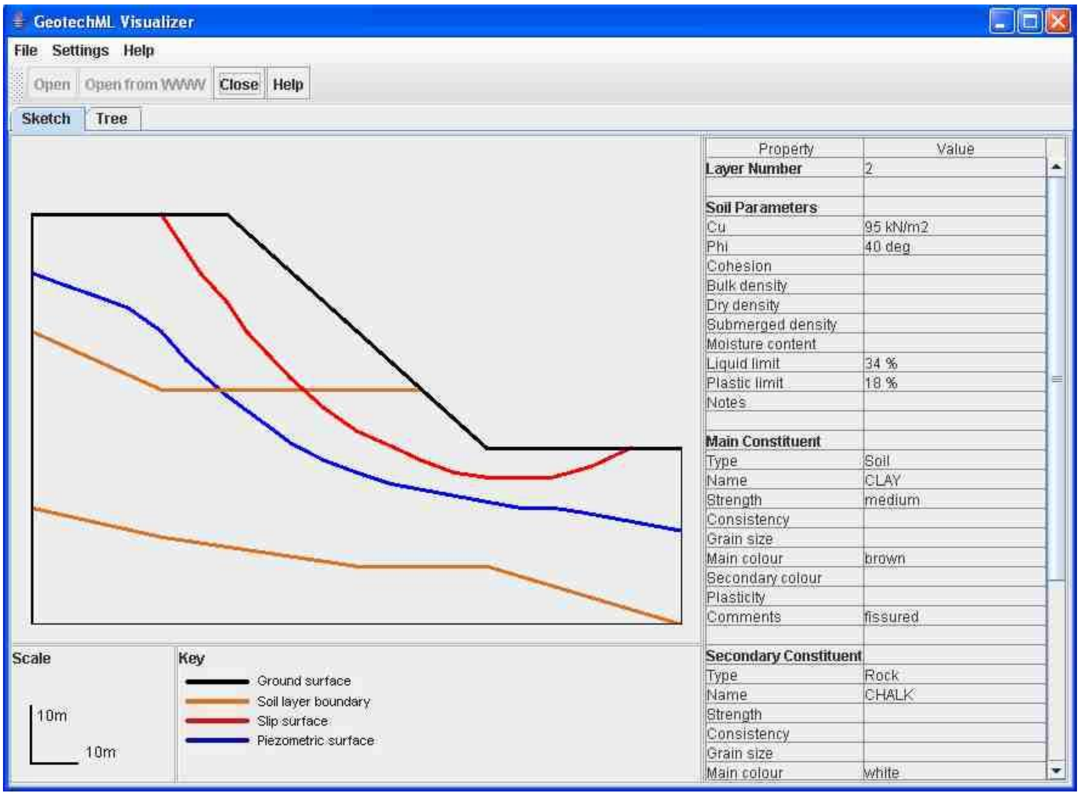


Level 3: Coordinate Representation

Figure 1. Three levels of representation for the same slope

It is therefore essential that a representation scheme is capable of operating at any of these different levels of representation. Figure 1 shows how three different levels of topographic detail can be used to satisfy the varying requirements.

At Level 1 the slope is defined simply by an overall slope angle and overall slope height (or Crest and Toe elevations). At Level 2 the slope is divided into segments (each referenced by height above the toe) which can be described as Slope Segments (defined by angle/height), Bench Segments (primarily defined by bench width) or Wall



Property	Value
Layer Number	2
Soil Parameters	
Cu	95 kN/m2
Phi	40 deg
Cohesion	
Bulk density	
Dry density	
Submerged density	
Moisture content	
Liquid limit	34 %
Plastic limit	18 %
Notes	
Main Constituent	
Type	Soil
Name	CLAY
Strength	medium
Consistency	
Grain size	
Main colour	brown
Secondary colour	
Plasticity	
Comments	fissured
Secondary Constituent	
Type	Rock
Name	CHALK
Strength	
Consistency	
Grain size	
Main colour	white

Figure 2. A Two-dimensional Graphical Representation of a Slope using GML

Segments (primarily defined by wall height). Of course, each segment can have other properties attached, such as surface cover or geomophological descriptions. At Level 3 the topography is defined by individual coordinates allowing a very detailed topographic representation (in 2D or 3D).

A listing of an XML structure for representing the data is shown in the Appendix. This is for illustrative purposes only; it is not intended to provide a complete representation or properly conform to the requirements of a GML application.

The first section of the XML file defines the locational and reporting data. The first three elements <gml:id>, <gml:description> and <gml:name> are for compatibility with GML and provide a unique identifier, a description and a name. The elements <Locality>, <NationalID> and <ReportDate> are provided for compatibility with the IAEG suggested method (Working Party on World Landslide Inventory, 1990). However, position information uses a <Location> element defined by <gml:point> as recommended by Toll (2007). Reporting data uses the "Roles" construct used by DIGGS (Data Interchange for Geotechnical and Geoenvironmental Specialists) (http://www.diggsml.org/) to define a person or organisation. In addition, a <DataSource> element is provided as landslide reports may be taken from published literature.

The Overall level (Level 1) contains data on crest and toe position, slope height/angle/shape and aspect. It also allows storage of Upslope and Downslope information, including nearby features (roads, rivers, buildings etc).

The use of GML to represent a 2D slope in terms of topography, layers of soil or rock (including geotechnical properties), ground water table and a failure surface is described by Majoribanks *et al* (in preparation). The Level 3 data is based on this proposal. The <Geometry> element uses GML constructs (e.g. <gml:point>, <gml:curve> or <gml:surface>) to represent a surface. Figure 2 shows a Java application to display the GML data graphically within a web browser.

Different levels of representation will also be needed for geological and geotechnical data. This may include (1) assigning a stratigraphic unit (2) identifying lithological, geomorphological or land-use units (3) providing a full engineering descriptions of the soil or rock (4) defining geotechnical parameters. The flexibility and hierarchical structure of XML can allow these different levels of representation to co-exist.

GML provides a full three-dimensional coordinate scheme. The developing Geoscience data standard (GeoSciML) will also support the use of three-dimensional geological models. GeoSciML is itself an application of GML and therefore will be compatible with applications developed using GML.

Representation schemes for ground investigation data such as those proposed by Toll and Shields (2003), Chandler *et al* (2006) and DIGGS can be used as the basis for defining geotechnical data. However, the form of representation for slopes will need to incorporate idealisations in the form of a ground model and simplified geotechnical parameters that would be used in stability analyses. Majoribanks *et al* suggest the need for an “interpreted” geotechnical data set that can be linked to the “raw” data obtained from a ground investigation.

6 CONCLUSIONS

It is recommended that a standard representation scheme should be developed for slopes and landslide data. The scheme will form part of a larger initiative to develop standard representation schemes for geo-engineering data. The work is being overseen by Joint Technical Committee 2 of the three international geo-engineering societies.

The scheme will need to have the flexibility to represent the data at varying levels of detail in order to suit the needs of the different professional groups who use slope data (geotechnical engineers, geomorphologists, geologists, planners etc). The use of XML (eXtensible Markup Language) can provide this flexible structure. The scheme can also make use of GML (Geography Markup Language) and GeoSciML (GeoScience Markup Language).

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APPENDIX

```
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      </Slope>
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Practice of establishing China's Geo-Hazard Survey Information System

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China Geological Survey[1], China University of Mining and Technology[2]

ABSTRACT: Based on the geo-hazards survey of seven hundred counties in China, with each county as a unit, the Geo-Hazard Survey Information System gathers national geo-hazard survey information and provides the functions of statistical analysis and assessment. The system contains a fundamental geo-hazard database, which is the most complete in the nation. The database includes geo-hazard information such as landslides, rockfalls, debris flows, ground fissures and unstable slopes and so on. The amount of survey information of geo-hazard locations and hidden danger spots in the database is more than one hundred thousand. The significance is to reduce the geo-hazard loss as much as possible by finding out the current situation and the development trend, assessing the situation of geo-hazards and danger, identifying the susceptible regions and the dangerous regions and hence suggesting prevention plans and arrangements.

1 INTRODUCTION

With the development and application of information technology, geologic information can be used not merely for intuitionistic browsing and simple visual judgment but for comprehensive analysis and application. The traditional information communication mode is unable to adapt to the requirements for information gathering. It requires an entire solution, including data processing, data management, information analysis and information publication. By the means of information technique, the solution can manage and analyze the information combining data and geologic information, which can make decision intuitively by adding geographical analysis to various information systems and discovering implicit relations, rules and changing trends. The Geo-Hazard Survey Information System is an efficient method for achieving this.

Since the geo-hazard warning project was launched, we have carried out geo-hazards surveys and developed regional plans in seven hundred counties. The rationale is that it reduces the geo-hazard loss as much as possible by finding out the current situation and the development trend, assessing the situation of geo-hazards and danger, identifying the susceptible regions and the dangerous regions and hence suggesting prevention plans and arrangements, advancing the monitoring network and combining experts, using a county as the basic unit. The Geo-Hazard Survey Information System, which is based on the survey and GIS platform, gathers national geo-hazard survey information and provides the functions of statistical analysis and assessment. The database includes geo-hazard information such as landslides, rockfalls, debris flows, ground fissures and unstable slopes and so on. The amount of survey information of geo-hazard locations and hidden danger spots in the database is more than one hundred thousand.

The system results in a geo-hazard database, which is the most complete in the nation. The establishment and improvement of the database provides rapid and valid information services for geo-hazard prevention and control and national geo-environment management. Meanwhile, it accelerates geo-hazard survey, monitoring, prevention and control.

2 MAIN FRAMEWORK OF THE SYSTEM

The system bases the main workflow of geological survey on information, made up of information gathering, information transmission, information processing and information services. The system provides the corresponding functions according to the application demand of the users. The main functions include data input, field data collection, data quality control, data summary, data management, data query, data statistics, data publishing and data display and so on. The system has three modules: data collection module, data management module and data service module. The main framework of the system is shown in Figure 1.

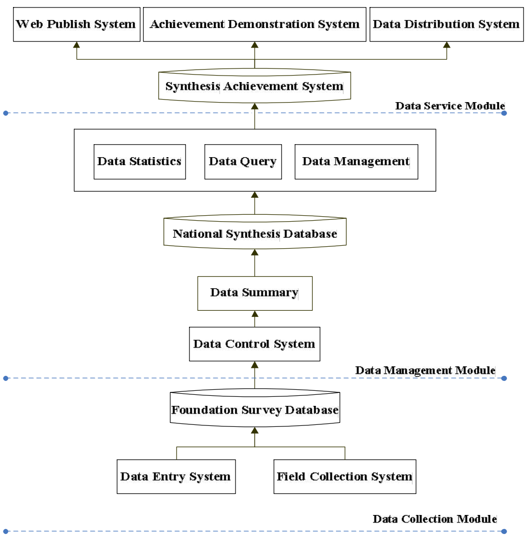

Figure 1. The system main framework

Every function is designed for specific users and usage stages. The data collection module is mainly used to collect data, edit data and enter it in the library according to system requirements and a unified data collection standard, to ensure data consistency and integrality, thus providing a solid foundation for the following multiple utilization of data. The data management module can be mainly used at the stage of summary and application of data. It can summarize survey data of different regions and provide the function of query, statistics and auxiliary processing for data managers and users. It manages data effectively and provides powerful technology support for data synthesis application and development. The data service module provides services for different data users. It can publish synthesis data, show thematic data and distribute custom data.

The query and statistics functions provide powerful technology support for comprehensive analysis of geo-hazards. The auxiliary processing can generate many types of statistical distribution maps. An example is the the geo-hazard distribution map of developmental degree, as shown in Figure 2.

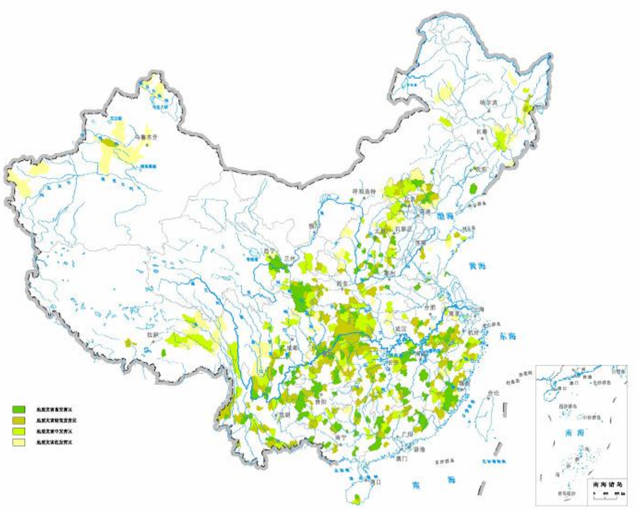

Figure 2. The geo-hazard distribution map of developmental degree

The system can take statistics conveniently and reproduce the result data as a set of diagram.

(1) Statistical diagram of the geo-hazard occurrence time

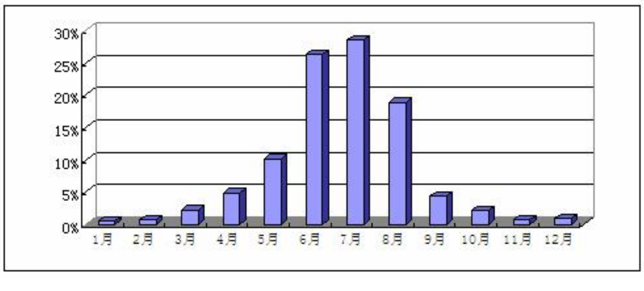

Figure 3. Statistical diagram of the geo-hazard occurrence time

(2) Statistical diagram of the geo-hazard scale

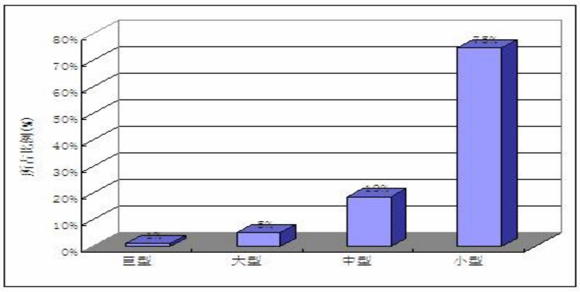

Figure 4 Statistical diagram the geo-hazard scale

(3) Statistical diagram of landslide type

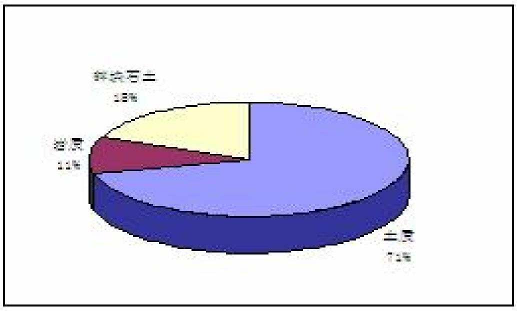

Figure 5. Statistical diagram of landslide type

3 SYSTEM DATA MODEL

To collect, manage and apply geo-hazard survey production data are the main functions of the system. The data includes landslide data, rock fall data, debris flow data, sinkhole data, ground fissure data, hidden hazard data (unstable slope) and so on. It also includes production reports and correlative production diagrams.

The core of the system is data. Data modeling is the key to how to organize and manage data so that the system can express the geo-hazard phenomena completely, then, users can query, process and analyze data conveniently. The design of the geo-hazard data model adopts a method combining classic modeling and object-oriented modeling. The data model allows different thematic elements to be abstracted from some thematic layers in the form of points, lines and polygons. By internal attribute correlation, the geo-hazard object-entity attribute is correlated. Then both organization and management of space data and consistency of multi-data are assured, so that GIS and database system show the advantages for spatial information management.

By researching the application characteristics of GIS in a professional field, the system modeled national geo-hazard data and provides a solid foundation for professional fields. The geo-hazard data model is shown in figure 6. For designing the data model, we considered the following characteristic of geo-hazard survey information sufficiently.

(1) Performance Characteristics of Analyzing and Processing

The purpose of the geo-hazard survey information is the comprehensive analysis and utilization of data, especially of spatial information. For data related spatial analysis, the size is very huge and the sources are multiple.

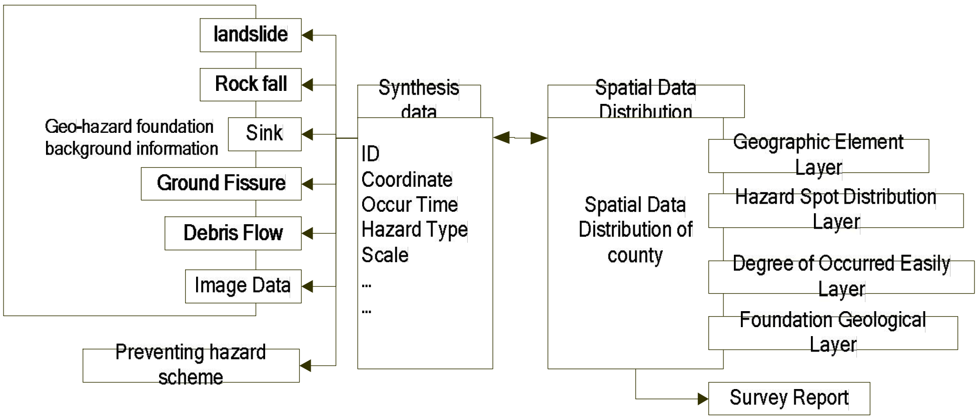

Figure 6. The geo-hazard data model

Spatial analysis takes up lots of time, but it is not a simple data query. Therefore considering the availability of data is essential.

(2) Integration Characteristics of Multi-data
The geo-hazard survey information contains vectors which describe spatial distribution, geo-hazard spot attribution, unformatted documents and images. For valid analysis and decision it is the initial premise that the multi-data is integrated and managed. The more completely the related data collected and the closer the connection is, the more credible the result is.

(3) Dynamic Characteristics of Data
The managed data is finished by survey only once, but geo-hazard spot may change with time. Thus the dynamic characteristic of the data should be considered when designing the data model.

(4) Comprehensive Characteristics of Data
The current survey achievement is mainly fundamental information, including a great deal of data which reflects geo-hazard feature details. But this detailed data is not analyzed. It is necessary to synthesize the detail data to get useful information before analysis. Therefore, to synthesize data and extract data conveniently are necessary, meanwhile data mining and data aggregation should be supported.

The landslide data structure table is shown in Table 1. The rock fall data structure table is shown in Table 2.

4 DATA QUALITY GUARANTEE

With the geo-hazard survey, we have developed the information system gradually since 1999. All departments participated in the work. So the quality of the system is particularly important. The outcome of having incorrect or inaccurate information is an incorrect or inaccurate result and corresponding decision. As a result, loss could be huge. Therefore the data quality guarantee is very crucial.

The system implementation conforms to ***The work guide of geo-hazard survey information system construction*** and ***The standard of geo-hazard data quality control***, by researching IS0 9000 19113 and 19114, and by referring to DZ/T 0179-1997, DZ/T0160-95 and ***The work guide of geological map spatial database construction (2nd edition)***.

Based on geo-hazard data characteristics, the factor system of data quality was established, including Level 1 quality elements, such as data integrality, logic consistency, spatial location accuracy, thematic data accuracy and map decoration appropriateness, and Level 2 quality elements. The factor system of data quality is shown in Table 3.

Table 3. Factor System of Data Quality

Level 1 quality elements	Description	Level 2 quality elements	Description
data integrality	Entity, entity attribute, entity relationship exists or not	redundant	redundant degree of data in a data set, such as redundant layer, spatial entity
		absence	absence degree of data in a data set, such as absence layer, spatial entity
logic consistency	consistency degree of logic rule about data structure, attribute and relationship	concept consistency	consistency degree to structure design, such as to database structure design
		domain consistency	consistency degree of value to domain, such as consistency of relationship to other domain
		format consistency	match degree about data storage to physical structure of data set，such as data file name or data format
		topology consistency	accuracy of topology feature, such as polygon close or not, node relation correctness
spatial location accuracy	Accuracy of spatial entity location	Math foundation Accuracy	Accuracy of map contour spot, point of intersection on coordinate system and reference point coordinate, Accuracy of coordinate, height datum, parameter and map projection
		emendation Accuracy	rationality of number and distribution of reference spot, accuracy degree of projected data
		collection accuracy	accord degree of spatial entity location to acceptable value or real value, such as scan and vector precision, spot spatial data location precision
thematic data accuracy	Accuracy of ration attribute, accuracy of qualitative attribute, entity and attribute classification	classify accuracy	accord accuracy of entity and its attribute classify to real value or a reference data set
		qualitative attribute accuracy	such as input accuracy of hazard spot attribute
		ration attribute accuracy	such as accuracy of value
map decoration appropriateness	Configuration of color, pattern, symbol and line type, Specification of map name, map number, legend, figure and inlay	Symbol appropriateness	correct symbol, accuracy location, reasonable denotation, symbol and symbol, relationship rationality of symbol to symbol and symbol to other map member
		Line appropriateness	correct line type, lubricity line
		Color appropriateness	appropriateness of professional color palette standard and rule
		pattern appropriateness	pattern type, color, height, width and transparent coefficient is correct or not
		Graph Structure rationality	measure map contour contain and appearance, reasonable map structure, handsome
		annotation appropriateness	Correct and readable annotation, rationality of parameter and boundary relation

Table 1. Landslide Survey Data Structure Table

Field name	Data type	Required	Description	Unit
ID	Char	Yes	●	
Project name	Char	No		
Mapsheet name	Char	No		
Mapsheet ID	Char	No		
Name	char	Yes		
Field ID	char	Yes		
General ID	char	Yes		
Location	char	Yes		
GPS longitude	Single	Yes	●	degree
GPS latitude	Single	Yes	●	degree
GPS altitude	Single	Yes	●	meter
longitude	Single	Yes		degree
latitude	Single	Yes		degree
Top of slope	Single	Yes		meter
Foot of slope	single	Yes		meter
Slide time	char	Yes	single select	
Occurring time	char	No		
Landslide type	char	Yes	single select	
Landslide property	char	Yes	single select	
Stratum epoch	char	Yes	single select	
Stratum lithology	char	Yes	multi select	
Stratum incline	int	No		degree
Stratum dip angle	int	No		degree
Structure location	char	No		
Seismic intensity	char	Yes	single select	
Micro topography	char	Yes	single select	
Ground water type	char	Yes	multi select	
Annual rainfall	single	No		millimeter
Max day-rainfall	single	No		millimeter
Max hour-rainfall	single	No		millimeter
Flood level	single	No		meter
Low water level	single	No		meter
Location to river	char	Yes	single select	
Origin slope height	single	Yes		meter
Origin slope gradient	single	Yes		degree
Slope type	char	Yes	single select	
Slope structure type	char	Yes	single select	
Length	single	Yes		meter
Width	single	Yes		meter
Thickness	single	Yes		meter
Area	single	Yes		Square meter
Volume	single	Yes		Cubic meter
Landslide slope gradient	Integer	Yes		degree
Landslide slope aspect	Integer	Yes		degree
Plane shape	Char	Yes	single select	
Section shape	char	Yes	single select	
Slide body lithology	char	Yes	multi select	
Slide body structure	char	Yes	single select	
Gravel content	char	No		%
Size of block	char	No		centi meter
Slide base epoch	char	Yes	single select	
Slide base lithology	char	Yes	multi select	
Slide base incline	Integer	Yes		degree
Slide base dip angle	Integer	Yes		degree
Slide plane shape	Char	Yes	single select	
Slide plane buried depth	Integer	Yes		meter
Slide plane cline	Integer	No		degree
Slide plane dip angle	Integer	No		degree
Slide zone width	single	No		meter
Slide zone soil name	char	No		
Slide zone soil property	char	No		
Ground water buried depth	single	No		meter
Ground water out crop	char	No	multi select	
Supply type	char	No	multi select	
Land use	char	Yes	multi select	
Structural area type no.1	char	No		
Structural area incline no.1	Integer	No		degree
Structural area dip angle no.1	Integer	No		degree
Structural area type no.2	Char	No		
Structural area incline no. 2	Integer	No		degree
Structural area dip angle no.2	Integer	No		degree
Deformation name no.1	Char	No	single select	
Deformation location no.1	Char	No		
Deformation feature no.1	Char	No		
Deformation time no.1	Char	No		
Deformation name no.2	Char	No	single select	
Deformation location no.2	Char	No		
Deformation feature no.2	Char	No		
Deformation time no.2	Char	No		
Geological factor	Char	Yes	multi select	
Topography factor	Char	Yes	multi select	
Physical factor	Char	Yes	multi select	
Man-made factor	Char	Yes	multi select	
Dominator factor	Char	Yes	single select	
Induced factor to relive	Char	Yes	multi select	
Present state	Char	Yes	single select	
Developing trend	Char	Yes	single select	
Death toll	Integer	Yes		person
House damage	single	Yes		room
Road damage	single	Yes		meter
Trend damage	single	Yes		meter
Other damage	char	No		
Direct loss	single	Yes		ten thousand RMB
Indirect loss	single	Yes		ten thousand RMB
Hazard type	char	No		
Influential range	char	No		
Loss	single	No		ten thousand RMB
Threaten population	integer	Yes		person
Threaten wealth	single	Yes		ten thousand RMB
Monitoring suggestion	char	Yes	multi select	
Prevention suggestion	char	Yes	multi select	
Plane drawing	char	No		
Section drawing	char	No		
Survey company	char	Yes		
Survey manager	char	Yes		
Fill in person	char	Yes		
Check person	char	Yes		
Filling date	char	Yes		
System version	char	Yes	●	
Data mask	char	Yes	●	
Save time	char	Yes	●	
Data file	char	Yes	●	
Collection system_ID	integer	Yes	●	

Table 2. Rock Fall Survey Data Structure Table

Field name	Data type	Required	Description	Unit
ID	char	Yes	●	
Project name	char	No		
Mapsheet name	char	No		
Mapsheet ID	char	No		
Name	char	Yes		
Field ID	char	Yes		
General ID	char	Yes		
Location	char	Yes		
Slope type	char	Yes	single select	
GPS longitude	single	Yes	●	degree
GPS latitude	single	Yes	●	degree
GPS altitude	single	Yes	●	meter
longitude	single	Yes		degree
latitude	single	Yes		degree
Top of slope	single	Yes		meter
Foot of slope	single	Yes		meter
Stratum epoch	char	Yes	single select	
Stratum lithology	char	Yes	multi select	
Stratum incline	Integer	Yes		degree
Stratum dip angle	integer	Yes		degree
Structure location	char	No		
Seismic intensity	char	Yes	single select	
Micro topography	char	Yes	single select	
Ground water type	char	Yes	multi select	
Annual rainfall	single	No		millimeter
Max day-rainfall	single	No		millimeter
Max hour-rainfall	single	No		millimeter
Flood level	single	No		meter
Low water level	single	No		meter
Location to river	char	Yes	multi select	
Land utilize	char	Yes	multi select	
Slope height	single	Yes		meter
Slope length	single	Yes		meter
Slope width	single	Yes		meter
Slope degree	integer	Yes		degree
Slope incline	integer	Yes		degree
Slope plane type	char	Yes	single select	
Rock structure type	char	Yes		
Thickness	single	Yes		meter
Cranny group number	char	Yes		
Size of block	char	Yes		meter
Slope structure type	char	Yes	single select	
Structural area type no.1	char	No		
Structural area incline no.1	integer	No		degree
Structural area dip angle no.1	integer	No		degree
Structural area length no.1	single	No		meter
Structural area internal no.1	single	No		meter
Structural area type no.1	char	No		
Structural area incline no.1	integer	No		degree
Structural area dip angle no.1	integer	No		degree
Structural area length no.2	single	No		meter
Structural area internal no.2	single	No		meter
Rotten zone depth	single	No		meter
Non-load cranny depth	single	No		meter
Soil name	char	No		
Density	char	No	single select	
Degree of denseness	char	No		
underside bedrock lithology	char	No	multi select	
underside bedrock incline	integer	No		degree
underside bedrock dip angle	integer	No		degree
Underside bedrock buried depth	single	No		meter
Ground water buried depth	single	No		meter
Out crop	char	No	multi select	
Supply type	char	No	multi select	
Deformation name no.1	char	No	single select	
Deformation location no.1	char	No		
Deformation feature no.1	char	No		
Deformation time no.1	char	No		
Deformation name no.2	char	No	single select	
Deformation location no.2	char	No		
Deformation feature no.2	char	No		
Deformation time no.2	char	No		
Unstable factor	char	Yes	multi select	
Stable degree	char	Yes	single select	
Changing trend	char	Yes	single select	
Death toll	single	Yes		person
House damage	single	Yes		room
Road damage	single	Yes		meter
Trend damage	single	Yes		meter
Other damage	char	No		
Direct loss	single	Yes		ten thousand RMB
Indirect loss	single	Yes		ten thousand RMB
Hazard type	char	No		
Influential range	char	No		
Loss	single	Yes		ten thousand RMB
Threaten population	single	Yes		person
Threaten wealth	single	Yes		ten thousand RMB
Monitoring suggestion	char	Yes	multi select	
Prevention suggestion	char	Yes	multi select	
Plane drawing	char	Yes		
Section drawing	char	Yes		
Survey company	char	Yes		
Survey manager	char	Yes		
Fill in person	char	Yes		
Check person	char	Yes		
Filling date	char	Yes		
System version	char	Yes	●	
Data mask	char	Yes	●	
Save time	char	Yes	●	
Data file	char	Yes	●	
Collection system_ID	integer	Yes	●	

The data check and quality evaluation methods result from the factor system of data quality. The data quality control software is developed for improving the accuracy and efficiency of data check.

5 CONCLUSIONS

Construction of the Geo-hazard Survey Information System is a complicated system engineering task, which is based on the geo-hazard survey data and applying information technology. The information technology relates to digital production technology, data quality control technology, spatial database technology, mass multi-mapsheet data organization and management technology, data share and publishing technology. The construction of the system is not a simple digital and software development, but also a huge innovational project utilizing information integrated technology. The achievement reflects systemic, professional, authority, reliability and superiority.

Database for Landslides and Engineered Slopes related to China's Water Resources Development using XML

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ABSTRACT: China is bestowed with abundant water energy resources, ranking at the first in the world in terms of hydropower. Stability of high slopes is an extremely prominent problem when developing these power stations. In this paper, the authors introduce briefly the database of slopes related to the water conservation and hydropower construction, including general information, the classification of the slope and the content of the database and so on. This slope database can provide important references for the design and construction of slopes in similar places in future. At present, XML (extensible markup language) technology is developing fast and is applied widely. XML supports data exchange between databases on the Web; it can provide network sharing of the database of slopes using XML. This paper introduces the work of establishing the web database for landslides and engineered slopes using XML technology.

1 PREFACE

China is bestowed with abundant water energy resources, most of which has not yet been developed. To-date, the installed capacity of hydropower accounts for about 24% of the state total power capacity. In the next 20 years, China will develop more large-scale hydropower projects. With the increasing number of huge dams and large-scale reservoirs, stability of high slopes will be one of the prominent concerns.

Collecting geologic and the geotechnical characteristics of engineered slopes related to hydropower development is believed to be of utmost important to understanding landslide mechanisms, and establishing reasonable analysis methods. The number of documents recording landslides is huge, but their styles, contents and levels are different. It is very difficult to utilize these record documentations if they are not undertaken in accordance with a unified methodology and format. Therefore, as early as in 1987, the work of registering landslides had started.

The landslide inventory requires the complete technical information of landslides or slopes in according with the specifically designed tables in order to build a database. In the past several years, China's water resources and hydropower workers had recorded 117 slopes with complete technical information, and published these documentations in the Web. These records will provide the reference for the design and the control of related slope projects. Fig. 1 shows the distribution of the 117 slopes and landslides related to China's hydropower development.

With the advent of the internet it is possible to create an internationally shared database for engineered slopes. Under such background, further work towards a web-based landslide and slope inventory has started.

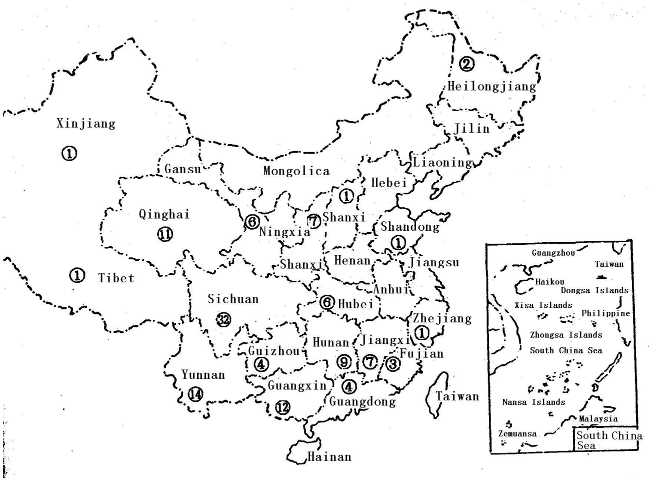


Figure1. The distribution of the 117 slopes and landslides in China (the number in each circle show the amount of slopes in the area)

In the past several years, XML (extensible markup language) technology has rapidly developed and found wide applications. Its advantages of having unique standardization, but expandable, have overcome HTML's shortcomings. It is more important that XML supports the data exchange between databases on web; we can enjoy the slope database on web by using XML technology. Now, in China, under the auspices of ISRM Commission on Case Histories in Rock Engineering, has begun some pioneering work.

2 BRIEF INTRODUCTION TO THE DATABASE

2.1 *Introduction*

The work of landslide inventory started in 1987, organized by an international initiative whose report provided the information, software and terminology of documenting landslides (Cruden and Brown, 1992).

From 1995 to 2000, under the background of “85” national key scientific and technological projects, the work of recording engineered slopes was carried on among China’s water resources and hydropower community. This work recorded the basic information of engineered slope case histories using standard methods that include geology, geotechnical properties and the slope material, design parameters, construction details, and instrumentation and monitoring information, etc. (Chen, 1992).

2.2 *The database*

The content of the registered slopes covers comprehensive information that includes:

(a) Basic information: the type of slope, the geography information, the main character, the stability situation, the factor of destruction, the general description and so on.

(b) Engineering geology: rock mass structure type, lithologic character, joint, ground water, competence, earthquake, plane figure, sectional drawing, joint statistics, and rock mass quality and so on;

(c) Geotechnical mechanical character: physical and mechanical property tests of soil (within a rock mass), field tests, crustal stress tests;

(d) Design of the slope: Stability analysis, design parameters, government situation and so on;

(e) Excavation: the construction of the slope: the locations of slope excavation, the blasting technology, the situation of projectile filling, the parameters of powder holes, the security measures, the security situation of the slope, measured ground speed, acceleration and so on;

(f) Instrumentation and monitoring: Monitoring projects, instruments and arrangement, observation data and so on;

(g) The recording of slope failures and destabilization: general information, the loss situation, the landslide geometry, shape and size, failure situation, adopted engineering measures, the landslide details (sectional drawings) and so on;

(h) References: internal literature, published literature and picture and so on.

2.3 *Classifications of the database*

2.3.1 *Classifications based on the types of the slopes*

According to slope properties, engineered slopes for water conservation and hydropower can be divided into three kinds: excavation slopes, reservoir slopes and river bank slopes. The number of each kind of slope is in Table 1.

Table1. Statistics according to slope type

Classification	Excavation slope	Reservoir slope	River bank slope
Amount	42	46	29
Total		117	

2.3.2 *Classifications based on the height of the slopes*

Table 2 shows the classification and statistics of slopes registered in the documentation of the slope database based on the height of the slope.

From Table 2, one may find that in water conservation and hydropower engineering, most slopes have heights more than 100 meters, which is a prominent factor that affects the stability problems.

2.3.3 *Classifications based on the failure modes*

The failure modes of slopes include: landslide, avalanche, slide (plane, cambered surface, and wedge), topple, burst, lateral expansion, flow, and the compound mode. Statistics are shown in Table 3.

Table2. The statistical results based on the height and stability status of slopes

Slope classification	*h*<10m		10m<*h*<50m		50m<*h*<100m		100m<*h*<200m		*h*>200m	
	Stability	Instability	Stability	Instability	Stability	Instability	Stability	Instability	Stability	Instability
Excavation slopes	0	0	0	2	2	9	8	15	2	4
Reservoir slopes	1	0	0	0	1	0	6	2	18	18
River bank slopes	0	0	0	0	1	1	1	4	6	16

Table3. The statistical results of unstable slopes based on rock mass structures

Destruction type		Massive	Cataclinal	Ancataclinal	Orthoclinal	Disintegration	Loosening	Statistics	
								Number	Percent
Avalanche		1	1	2	1	0	1	6	8.6
Slide		8	10	2	6	2	23	51	72.9
Burst		0	2	0	1	0	0	3	4.3
Topple		0	0	4	0	0	1	4	5.7
Crack		1	0	0	1	0	0	2	2.8
Flow		0	0	0	0	0	0	0	0
Compound		0	1	2	1	0	0	4	5.7
Statistics	Total	10	14	10	10	26		70	100
	Percent	14.3	20.0	14.3	14.3	37.1			100

2.3.4 *Classifications based on the rock mass structures*

The rock mass structure of a slope can be divided into 6 types that are: massive, layered (including cataclinal, anaclinal and orthoclinal), disintegration and loosening. The statistical situation is shown in Table 4. The statistics result of each kind of rock mass structure of unstable slopes is shown in Table 3. According to the statistical results, slopes with bedding structures occupy the majority. The layered rock mass structure is further divided into three kinds of structures, namely: cataclinal, anaclinal and orthoclinal, for details, see Table 5. For failure modes of massive structure slopes, see Table 6.

The factors that trigger the failure can be divided into natural and man-made. The statistical results of 117 slopes in the water conservation and hydropower projects are shown in Table 7.

Table 4. The statistical results based on different rock mass structures

Rockmass construction	Massive	Synthetic layered	Reversal layered	Oblique layered	Disintegration	Loosening
Amount	14	26	15	17	3	42
Total	117					

Table 5. The statistical results based on the failure modes of inter-bedding slopes

Stability situtation	Number	Percent	Destruction type									Scale
			Avalanche	Slide			Topple	Crack	Burst	Compound	Flow	Volume (10^4m^3)
				Plane	Cambered surface	Wedge						
Instability	7	50	1	2	4							165~4200
Stability afterreating	2	14.3				1				1		22.64~30
Creep	5	35.7		2	1				2			7.0~1800
Total	4	100	1	4	5	1			2	1		

Table 6. The statistical results of massive slopes based on the failure modes

Stability Stitutation	Amount	Percent	Failure modes									Scale
			Avalanche	Slide			Topple	Crack	Burst	Compound	flow	Volume (10^4m^3)
				Plane	Cambered surface	Wedge						
Instability	3	30		1	1	1						5~9
Stability Afterreating	6	60	1	3		2						0.01~140
Creep	1	10				3		1				15.6
Total	3	30		1	1	1						5~9

Table 7. The statistical results based on the triggering factors of failures

Factor	Amount	Failure modes				Comment
		Stability	Percent	Distortion and destruction	Percent	
Water	62	30	48.4	32	51.6	Primarily large and middle scale or giant landslides
Storm rainfull	32	15	46.9	17	53.1	
Reservoir filling	18	10	55.6	8	44.4	
Groundwater	3	1	33.3	2	66.7	
Rain induced groundwater	6	3	50	3	50	
Erosion	3	1	33.3	2	66.7	
Human activity	44	12	27.3	32	72.7	Primarily middle and small scale wedge slide, crack and Large-scale avalanche
Excavation	41	12	29.3	29	70.7	
Mining	3	0		3	100	
Others	11	4	36.4	7	63.6	Topple, avalanche and burst, slide.
Gravity	7	3	42.9	4	57.1	
Earthquake	4	1	25	3	75	
Total	117	46	39.3	71	60.7	

3 THE APPLICATION OF XML IN THE DATABASE OF SLOPE RECORDS

3.1 *Introduction of XML*

XML is a markup language and similar to HTML in programming, a subset of SGML (the Standard Generalized Markup Language to generate the standardized document of ISO8879 published in 1986). It inherits the self-defined markup character, and changes the deficiency of HTML in function, to have a more extendable character.

XML has some features:

(1) Extendable. XML is a language to create markup, to create new markup to use. Thus its use level can be extended finitely;

(2) Simple to understand. XML code is text-based, unlike other database languages. So it can be edited by usual editing software. It expresses relationships directly and is easily understood;

(3) Information can be exchanged between different platforms. As XML is simple to understand, its format can be used to mark different data type. If there is an XML decoding system between the exchanging platforms, the right information can be obtained by interpreting the marked data;

(4) International. When XML was proposed, the international implications were considered. So it is founded on Unicode.

XML's files can be viewed by IE with the aide of CSS (cascading style sheets) and the extensible stylesheet language.

Because an XML-file is only used to store data, not including other information such as format etc., it is generally used to process the data. First an '.xsd' XML Schema file is created, to define the style and element character. To determine the requirements of the XML document, the '.xsd' files describes the character. It is necessary to use the same style material file in database storage. Another '.xsl' file is defined for how the XML document is viewed in a browser. The relation of XML file, '.xsd' and '.xsl' file is expressed as Figure 2:

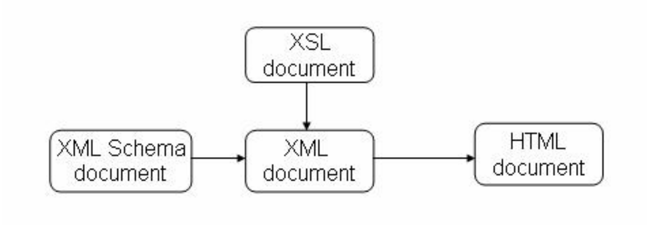


Figure2. The relationship of XML file, XML Schema and XSL document

3.2 *XML format of slope data file*

Based on the standard document of slopes, the structure file 'slopedata.xsd' was created, including all the main factors. The structure of the slopedata.xsd file is shown in Fig. 3:

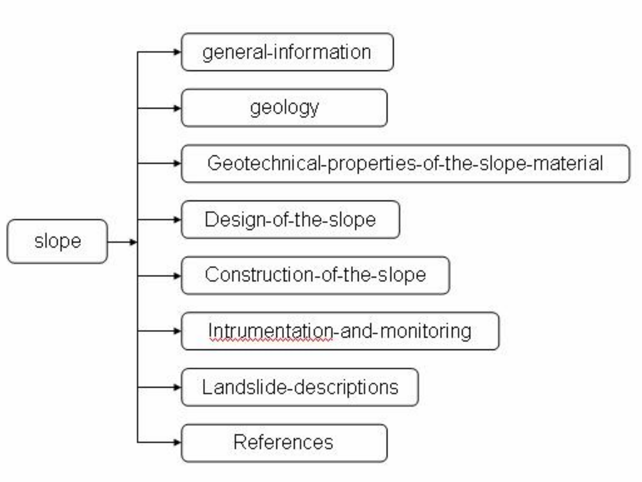
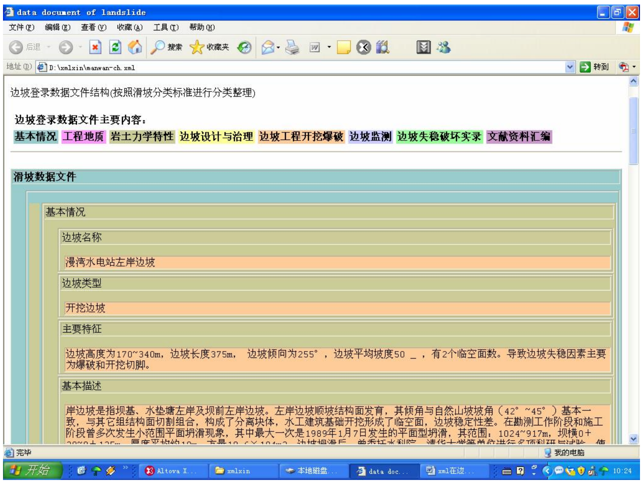


Fig 3. The structure of 'slopedata.xsd' file

In the tree-based structure, the information related to the individual structure is included for each slope case. Thus using the XML managing technology, the information can be described in detail. The combined XSL document can be displayed clearly in the user's browser.

3.3 *XML slope data file example*

Fig. 4 shows the XML data file 'manwan.xml' for the left bank slope in Manwan waterpower project using XML technology. By loading slopex.xsl, manwan.xml is displayed in IE6.0. The HTML output is shown in as Fig. 4.



边坡登录数据文件结构(按照滑坡分类标准进行分类整理)

边坡登录数据文件主要内容:

基本情况 工程地质 岩土力学特性 边坡设计与治理 边坡工程开挖爆破 边坡监测 边坡失稳破坏实录 文献资料汇编

滑坡数据文件

基本情况

边坡名称

漫湾水电站左岸边坡

边坡类型

开挖边坡

主要特征

边坡高度为170~340m, 边坡长度375m, 边坡倾向为255°, 边坡平均坡度50 _ , 有2个临空面数。导致边坡失稳因素主要为爆破和开挖切脚。

基本描述

岸边坡是指坝基、水垫塘左岸及坝前左岸边坡。左岸边坡顺坡结构面发育, 其倾角与自然山坡坡角(42°~45°)基本一致, 与其它组结构面切割组合, 构成了分离块体, 水工建筑基础开挖形成了临空面, 边坡稳定性差。在勘测工作阶段和施工阶段曾多次发生小范围平面坍滑现象, 其中最大一次是1989年1月7日发生的平面型坍滑, 其范围: 1024~917m, 坝横0+

Fig 4. The display of 'manwan.xml' file in IE6.0

3.4 *Use of XML database network share*

XML has many advantages in database applications. First, it is cross-platform. An XML file is a text-based file, not restricted only to a specific OS or software platform. Second, it is simple and straight-forward. XML has the ability of a Schema self-description which can be auto-processed by computers. Third, XML describes not only the structural data, but also the sub-structural, even non-structural data.

We are now constructing a slope database based on Internet share, combining the SQL Server 2000 and XML, incorporating the network programming technology. Figure 5 is the developed structure of a SQL Sever2000 and XML combined system. According to the different system of structure and service, different access components or protocols are used. Considering the capability and programming rationale, it is often useful to couple the logic and data accesses. Thus we can using the standard components to realize it, such as OLEDB, ADO and NET API and so on.

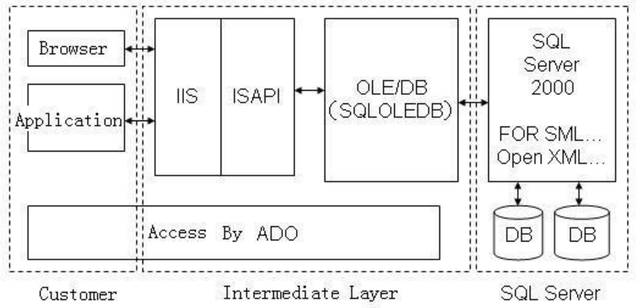


Fig 5. SQL Server’s XML access system

Through the above analysis, based on the database of slopes, we can add, search or browse the slope data file through the internet. From the internet, we can share the cherished resources of our world, and every engineer of each country can obtain their relevant slope data file. This job is complicated, will require much quality work, and many people to cooperate to achieve it. But it has been started, and in the near future, we believe it can share this data on the internet.

4 CONCLUSIONS

China is developing its water power quickly, especially in Southwest areas. Stability of high slopes has been a main concern. Collecting slope data files can provide valuable references for solving high slope problems.

The advanced network and computer technology have made a database of collected slope information possible. Now the generalized XML technology can realize the data transfer across platforms. It has simple readable and extensible characters. By the related knowledge of databases, it can provide network sharing of the database of slopes using XML.

The Chinese Committee of Rock Mechanics and Engineering is working on the establishment of a slope engineering database under the help of international committees. We believe, in the near future, information on geotechnical engineering around the world can be searched and browsed on the internet by using such slope files.

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