Administrative report of TC10 – Geophysical characterization of sites

Compte rendu technique de la No. CT 10 – Caractérisation géophysique des sites

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ABSTRACT: The activities of Technical Committee 10 are described. The scope of TC 10 is presented as well as the application of geophysical methods for the solution of geotechnical and geo-environmental problems is presented. TC 10 has carried out during the present term most of the anticipated activities, including the setting up of an interactive Web platform and the establishment of Geophysics Info, a database on geophysical methods. Other activities include participation in conferences and organisation of a Workshop on Geophysics.

RÉSUMÉ: Les activités du Comité technique N°10 sont décrites. Les activités du comité sont décrites et l'application des méthodes géophysiques pour la solution des problèmes géotechniques et geo-écologiques est présentée. Le comité a effectué pendant la periode actuelle la plu part des activités prévues, y compris l'établissement d'une plate forme interactive de Web et de l'établissement de l'information de géophysique, une base de données sur des méthodes géophysiques. D'autres activités incluent la participation dans les conférences et l'organisation d'un atelier sur la géophysique.

1 INTRODUCTION

1.1 *Background*

Technical Committee 10, Geophysical Characterisation of Sites (TC 10) was established in 1989, following the 12th International Conference on Soil Mechanics and Foundation Engineering (ICSMFE) in Rio de Janeiro. Sponsoring country was the United States of America, with Dr. R. D. Woods and Dr. K. Stokoe as Chairman and Secretary, respectively. At the following ICSMFE, held in New Delhi, India the committee published a state-of-practice report, "Geophysical Characterization of Sites", (Woods, 1994). This publication contains descriptions of geophysical methods as well as a Bibliography of geophysical publications. Following the 14th ICSMFE in Hamburg, Germany, the Swedish Geotechnical Society accepted sponsorship of TC. This report summarises the third working period of the committee.

1.2 *Members*

The membership of the committee at the end of the period 1997-2001 has been as follows:

Dr. K. Rainer Massarsch, Chairman, Sweden
Dr. A. Bodare, Secretary, Sweden
Dr. John Greenhouse, Core Group, Canada
Mrs. Deirdre A. O'Neill, Core Group, Italy/USA
Dr. Kohji Tokimatsu, Core Group, Japan
Dr. Richard D. Woods, Core Group, USA

Members:
Dr. G. A. Athanasopoulos, Greece
Mr. J. M. Barros, Brazil
Mr. T. Butcher, UK
Dr. R. Campanella, Canada
Dr. V. Cuéllar, Spain
Dr. A. K. Dhawan, India
Dr. G. Heymann, South Africa
Mr. E. Imre, Hungary
Dr. S-H. Joh, Korea
Dr. A. M. Kaynia, Norway
Dr. P. Klablena, Czech Republic
Dr. G. A. M. Kruse, Netherlands
Mr. R. Lagabrielle, France
Dr. B-S. Lee, Korea
Mr. J-L. Mattiuzzo, France
Dr. H. Maurer, Switzerland
Mr. G. Mitrovic, Croatia
Mr. P. O'Connor, Peter, Republic of Ireland
Dr. M. Oliveira, Portugal
Dr. S. Rybicki, Poland
Dr. J. C. Santamarina, USA
Mr. C. Schroeder, Belgium
Dr. E. G. Silva, Argentina
Dr. K. Stokoe, USA
Dr. U. Stötzner, Germany
Mr. E. Törös, Hungary
Dr. B. Whiteley, Australia

In addition, the Committee had 12 contact members, which had expressed interest in the activities of the committee.

2 TERMS OF REFERENCE

The goals of geotechnical and geophysical site characterization (GSC) are to provide the geotechnical engineer (designer, contractor, owner or authority) - based on the results of field investigations - with sufficiently detailed information in order to plan, design, construct and operate structures on, or below the ground. The main objectives of TC 10 are:

- To promote the co-operation, interaction and exchange of information and knowledge about the execution and interpretation of geophysical methods for geotechnical and geo-environmental site characterisation.
- In particular, to promote the dissemination of knowledge about the application of seismic techniques, to the solution of geotechnical problems.
- To encourage the involvement of equipment manufacturers and software developers in the activities of the committee.

• To co-operate with TC 29 (Stress-Strain testing of Geomaterials) and TC 16 (Ground Property Characterisation from In-situ Testing) and other national and international geophysical societies on applications of geophysical techniques.

TC 10 focused during 1998 - 2001 on the following activities:

1. Setting up of a Web Site on the Internet, possibly in co-operation with TC 16 and TC 29.
2. Organisation with TC 16 of the next International Conference on Site Characterisation to be held in 2002 (ISC'02) and to co-operate in the planning of a session in the GeoEng 2000 conference.
2. Planning, organisation and conduct of a session at the XV ICSMGE in Istanbul, Turkey.
3. Co-operation and liaison with national and international geophysical societies to promote the exchange of information and knowledge on geophysical techniques and interpretation
5. Cooperation with GeoEng 2000.

3 TECHNICAL SCOPE

Geotechnical and Geophysical Site Characterization (GSC) have become among the most important and rapidly developing areas of geotechnical engineering. In order to facilitate the introduction of new field investigation methods and their practical applications, the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE) sponsors two technical committees (TC 10 and TC 16), focusing on geophysical and geotechnical site characterization, respectively.

While the benefits and limitations of conventional geotechnical field investigation methods are generally understood and accepted by the profession, this is not the case - in the eyes of many geotechnical engineers – with respect to geophysical methods. These are still associated with a flair of "mysticism".

One reason may be the lack of understanding of the advantages and limitations of different geophysical methods (often unjustifiable expectations, which can not be satisfied), another the sometimes high degree of empiricism and judgement in connection when interpreting data. A third factor may be the lack of correlation between measured values and the anticipated geotechnical parameters. However, during the past decades, several geophysical methods have been developed into highly scientific tools, especially as a result of the powerful electronic measuring and data acquisition systems, sophisticated date interpretation and presentation methods. Today, geophysical methods are widely used in many different technical and other disciplines, such as:

- Civil Engineering
- Environmental Engineering
- Off-shore & Marine Engineering
- Earthquake Engineering
- Rock Mechanics & Tunnelling
- Mining & Exploration
- Forensic studies
- Archaeology
- Agriculture
- Space Engineering

There is an overlap of activities between several of the disciplines listed above. Despite differences of application of methods and objectives of investigations, as well as requirements for data interpretation, a closer cooperation and exchange of experience can only be beneficial for all groups using geophysical methods. Geophysical methods have several important advantages, compared with conventional geotechnical field investigation methods. They can explore relatively large soil volumes, of which they can identify material properties, material boundaries as well as variations in space and time. Many of the methods have the additional advantage of being non-destructive. In many cases, it is sufficient to place sensors on the ground surface (non-intrusive testing).

However, a major limitation is that in most cases, the measured parameters need to be correlated with engineering properties, a procedure which is not always straightforward and requires experience and judgement. In order to improve the reliability of geophysical investigations, it is advisable to combine several methods and to verify these by sampling and correlation with conventional geotechnical field and/or laboratory methods. Geophysical methods can be used for the identification and localization of different types of materials, Table 1:

Table 1. Materials, which can be detected by geophysical methods

Geologic materials	Clay, silt, sand, gravel, stones, rock, with inclusions of minerals, ore or metals
Water	Ground water, but also as vapour or ice
Man-made fills	Landfills, waste deposits and other man-made objects
Construction material	Steel, concrete, asphalt, timber
Chemicals substances	Pollutants, such as hydrocarbons, acids etc
Voids	Micro- and macro voids

4 GSC INVESTIGATION PROCESS

The process of geophysical site characterization can be complex and the investigation methods must be chosen carefully and depending on the parameters, which are needed for the specific project. The GSC process can be divided into several different phases: determination of the general engineering-geological situation (based on local experience, geological information and maps, remote sensing etc.). The next step is to establish the stratification (vertical variation of soil and rock layers and of ground water horizon) and their lateral distribution (variation). Table 2 gives an overview of parameters, which can be measured by geophysical methods.

Table 2. Geophysical measurements

- Mechanical wave field, for instance seismic measurements
- Electromagnetic waves (Microwaves) Ground Penetrating Radar (GPR)
- Electromagnetic field
- Electric resistivity
- Magnetic field
- Gravity
- Temperature
- Optical information (vision)
- Nuclear radiation (Neutron)
- Tracers (mechanical and chemical)
- Dielectric properties (logging)
- Acidity (pH-value)
- Redox potential (hydro carbons)
- Laser-induced fluorescence
- Nuclear-magnetic resonance

A detailed description of the applications and limitations of standard geophysical methods can be found in the Corps of Engineers (WES) Engineering and Design Manual "Geophysical Exploration" (1979). Several of the above listed methods have been

introduced as a result of recently developed geo-environmental investigation methods, Robertson et al. (1998). The application of the cone penetration test (CPT) for geophysical site characterization opened new possibilities for geophysical site characterization. The CPT has rapidly gained acceptance and is recognized as a valuable in-situ testing technique because of its speed, reliability, cost-effectiveness and excellent soil profiling capability.

Frequently used geophysical methods, which can be applied to identify geologic formations, are listed in Table 3. Also, several recently developed methods especially for geo-environmental investigations are also listed. For a more detailed description of these methods and information concerning data interpretation of the various methods, reference is made to Greenhouse et al. (1998), Robertson et al. (1998), WES Engineering Manual (1979) and Triumf (1992).

Table 3. Measurement of geotechnical properties determined by Geophysical Site Characterization

Electromagnetic methods (Active or passive measurement of variations in magnetic field):
Distribution of clay deposits, salinity of groundwater, contamination in groundwater, fault zones and fractures in rock, rock formations

Dielectric constant:
Dielectric constant is very sensitive to contamination, used in combination with CPT

Electrical Resistivity (Active measurement of electric resistance - electric conductivity - and variation in electric field):
Material type and porosity, groundwater, layer thickness, water quality and contamination, corrosion, cavities.

Gravity (Variation in gravitational field, gravity intensity):
Detects rock structures and buried ridges, faults and cavities.

Laser induced fluorescence - LIF (Fluorescence emission):
Can detect hydrocarbons, sensor mounted on tip of CPT

Magnetic methods (Passive measurement of variation in earth's magnetic field):
Determines presence and location of magnetic material, soil and rock formations and indication of age, can locate ore bodies or steel objects.

Nuclear magnetic resonance (NMR) (Presence of protons):
Responds to water directly, grain size of granular material, still in development stage

PH:
Acidity of material

Radar - GPR (Travel time and amplitude of electromagnetic waves):
Profiles soil type and layering, ground water level and presence of anomalies and cavities

Radiation, Neutron Activity (Natural radioactivity and concentration of selected radioactive elements):
Concentration of selected radioactive materials, lithology, correlation with soil and rock strata, indication of density and permeability, clay strata and radioactive minerals

Redox Potential (Measures organic exchange capacity):
Used in combination with CPT for identification of acids and inorganic substances

Seismic methods (Travel time and amplitude of signal):
Compression, shear and Rayleigh wave velocity: related to soil and rock type, (groundwater) and material stiffness (modulus at small strain level)

Vision:
Image of penetrated material, from borehole or mounted in CPT tip

5 FUTURE TRENDS IN GSC

In the area of geotechnical engineering, four major trends can be identified: 1) incorporation of geophysical sensors in geotechnical testing equipment, such as the CPT. 2) improved correlation between measured geophysical parameters and geotechnical and geo-environmental parameters, 3) increased use of geophysical methods for monitoring of changes in material properties (and ground water properties) in space and time and 4) the impact of powerful electronic and computer technology on field measurements, data analysis and presentation.

6 COMMUNICATION AND INFORMATION EXCHANGE

One of the primary objectives of TC 10 during the current period was to develop a platform on the Internet for efficient communication with, and dissemination of information between members of TC 10 and others interested in GSC.

As a first step, a traditional Web site was established as part of the Web presence of the Swedish Geotechnical Society (SGF). However, as such a Web site does note permit members of TC 10 to communicate with each other or to post information, it was decided to develop – with the support of SGF – an interactive Web Platform, Figure 1. The Web Platform offers members several different functions for communication, discussion and posting of documents.

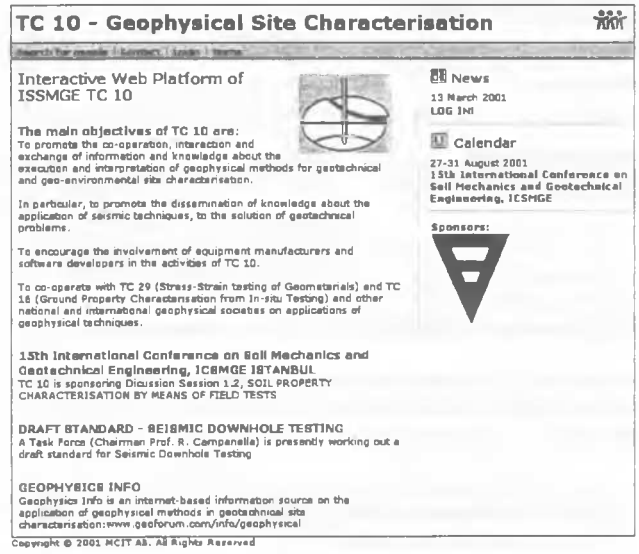

Figure 1. Start page of the interactive Web platform of TC 10 (www.geoforum.com/tc10).

The start page can be accessed directly from the Internet. However, the member area and functions of the Web platform can only be used by members, which can belong to different user categories (i.e. TC 10 members, contact group members or other participants). The advantage of the Web platform is that participants can use a variety of functions to post documents, to distribute information to different member groups by e-mail, to discuss topics in the Discussion Forum and to post and keep up to date their respective contact address as well as professional and personal information.

In addition to the Web Platform, a comprehensive geophysical information system (Geophysics Info) was created as part of the Internet-based geotechnical information service, "Geoforum.com" (www.geoforum.com), which is operated as an industry-independent geo-engineering community, Figure 2.

Geophysics Info contains different types of information, such as listings of geotechnical professionals (Geo Directory), of

companies and organisations, presenting commercial products and services (Geo Market Guide) and of events (conferences and symposia). In addition, technical topics can be discussed in the Discussion Forum. The web site also contains a searchable database, with a listing of geophysical publications, which were included in Woods, (1994), links to other organisations in the geophysics area as well as a News section. The Text & Publications section includes a description of geophysical methods to soil and rock engineering.

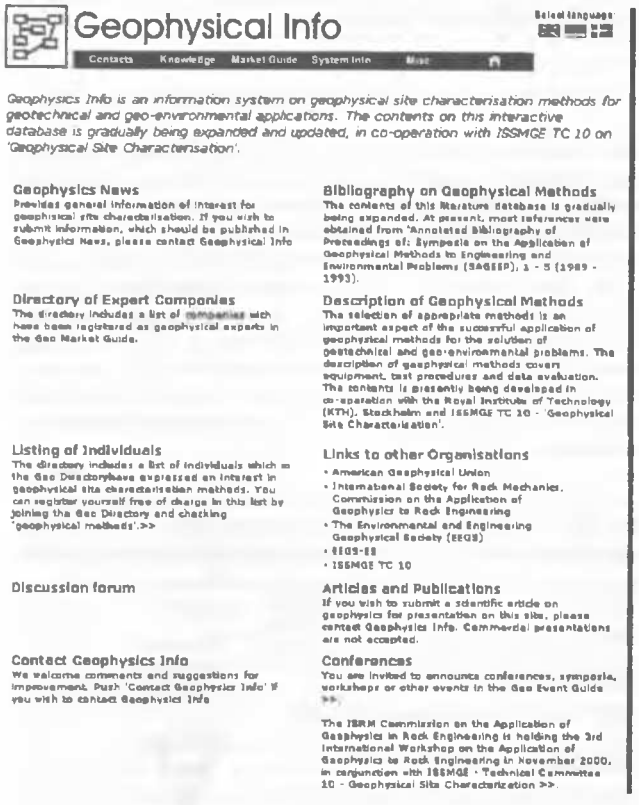

Figure 2. Start page of Geophysics Info, part of Geoforum.com

Members of TC 10 have received on average three Newsletters per year, which summarized the activities and presented new initiatives.

7 WORKSHOPS AND CONFERENCES

TC 10 participated actively in several conferences and workshops, such as the International Conference on Site Characterization (ICS'98) in Atlanta, USA, the 5th Meeting of Environmental & Engineering Geophysical Society (EEGS), European Section 1999 in Hungary, in 2000 in the conference "Advances in Engineering and Environmental Geophysics", a celebration of the UK Environmental and Industrial Geophysics Group (EIGG) and GeoEng2000 in Melbourne, Australia.

The International Society for Rock Mechanics (ISRM), Commission on the Application of Geophysics to Rock Engineering and TC 10 jointly organized an International Workshop on the « Application of Geophysics to Rock and Soil Engineering », in association with GeoEng2000 in Melbourne, Australia. The Workshop gave valuable opportunities to present and to discuss new applications of geophysical methods to soil and rock engineering problems.

Members of TC 10 took part in several conferences and symposia in Europe, North America and the Far East and contributed with papers on the development and practical application of geophysics in geotechnical and geo-environmental engineering.

TC 10 is also planning to participate actively in Discussion Session 1.2, "Soil Property characterisation by means of field tests" at the XV ICSMGE in Istanbul.

8 COMMITTEE MEETINGS AND TASK FORCE

TC 10 has held three meetings, in 1999 in Atlanta, USA (ISC'99), the second in 2000 in Melbourne, Australia (GEOENG 2000) and the third in Istanbul, Turkey (XV ICSMGE).

9 ACTIVITIES TO BE COMPLETED

During the latter part of the present term, TC 10 established a task force with the aim to develop a draft standard or reference document for seismic (down-hole) testing. Members of the Task Force are Dr. R. Campanella, Canada (convenor), Mr. T. Butcher, UK and Dr. A. Kainia, Norway. The main objective is to illustrate how seismic down-hole testing shall be performed, in particular when used as part of cone penetration testing (CPT). In order to demonstrate the usefulness of seismic testing for the solution of conventional geotechnical problems, it is planned to publish papers, which are aimed at the practising geotechnical community.

TC 10 anticipates also to co-sponsor another workshop on the application of Geophysics to Rock and Soil Engineering in co-operation with ISRM.

10 REFERENCES

- Greenhouse, J. Pehme, P., Coulter, D & Yarie, Q. 1998. Trends in geophysical site characterization. Theme lecture, Geotechnical Site Characterization, Balkema, Rotterdam, pp. 23 – 34.
- Roberson, P. K., Lunne, T. & Powell, J. J. M. 1998. Geo-environmental applications of penetration testing. Theme lecture, Geotechnical Site Characterization, Balkema, Rotterdam, pp. 35 – 48.
- Triumf. C-A. 1992. Geofysik för geotekniker (geophysics for geotechnical engineers). In Swedish. Byggforskningsrådet., Stockholm, 84 p.
- WES Engineering Manual. 1979. Engineering and Design – Geophysical Exploration. Department of the Army, Corps of Engineers
- Woods, R. D. (Ed.). (1994). Geophysical Characterization of Sites. Volume prepared by ISSMFE Technical Committee # 10 for XIII ICSMFE, New Delhi, India. Oxford & IBH Publishing Co. PTY. LTD. Pp. 141.