STATENS GEOTEKNISKA INSTITUT
SWEDISH GEOTECHNICAL INSTITUTE

R&D for Roads and Bridges

International Seminar on Soil Mechanics and Foundation Engineering

BENGT RYDELL (ED)

Report 46

LINKÖPING 1995

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Rapport
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Preface

Close co-operation in the field of geotechnical research has existed for many years between the Swedish National Road Administration (SNRA) and the Swedish Geotechnical Institute (SGI). In 1992, a seminar on road design, construction and maintenance related R&D was held with invited researchers from the Nordic countries. As the offshoot of discussions between the SNRA and SGI, an international seminar on soil mechanics R&D for roads and bridges was found to be valuable. The objective of this seminar was to stimulate and encourage co-operation between European countries.

Ten countries in Northern and Western Europe were invited to a seminar. The seminar was arranged by the SNRA and SGI and was held on November 16-18, 1993, in Sigtuna, Sweden.

This report contains the results from the plenary sessions and group discussions. Valuable comments have been made by some of the seminar participants. Papers, national reports on ongoing R&D and other publications were presented at the seminar and are included in a separate report called "Soil mechanics and foundation engineering R&D for roads and bridges. A summary of activities in the Northern and some Western European countries", SGI Varia 437.

Linköping, May 1995

Bengt Rydell
Editor

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Summary

In November 1993, the Swedish Geotechnical Institute (SGI) and the Swedish National Road Administration (SNRA) arranged a seminar entitled "Soil Mechanics and Foundation Engineering for Roads and Bridges". The objective was to identify mutual R&D needs and to encourage co-operation between European countries. A total of 30 invited participants from nine European countries attended the seminar.

Seminar programme

The following topics were chosen for discussions in plenary sessions and group discussions at the seminar.

- *Geotechnical design*
- *Foundation engineering*
- *Environmental geotechnics*

The topic "Control and quality assurance" was also discussed in one of the group discussions. An additional plenary session was held for discussions on "Dissemination and use of geotechnical knowledge".

As a basis for discussions, National Reports were compiled by participants from each country. A summary report was presented by the session chairman of each topic. In addition, a series of prepared presentations from different countries was given, related to a specific area of the session topic.

The presentations formed the basis for group discussions on research needs and potential co-operative R&D projects.

R&D areas and activities for potential future co-operation

The results of the group discussions were presented in a plenary session and the participants agreed on the following potential co-operative R&D activities.

Geotechnical design
- Application of Eurocode
- Probabilistic design
- Experimental data from test fields

Foundation engineering
- Geophysical methods
- Deep mixed-in-place methods

Environmental geotechnics
- Use of secondary materials
- Pollution control and prevention
- Slope protection/landslides
- Vibrations

Control and quality assurance
- Information exchange
- Development of methods for quality management

Dissemination and use of geotechnical knowledge

An important part of research work is to implement the results in practice. For that reason, a special session was held concerning the use of geotechnical knowledge and technology transfer. The discussions came to the conclusion that the transfer of knowledge must be improved. The most efficient activities are dissemination by technical standards, courses/education and experience from failures. The authorities have to force the industry to fund R&D to a greater extent. On the other hand, authorities must take greater responsibility concerning the implementation of R&D results.

Another important factor is to stimulate researchers at universities and research organizations to inform and implement the R&D results in practice. It is a challenge for all participants in the geotechnical field to find new ways to use relevant geotechnical knowledge in planning and construction.

Chapter 1.
Introduction

1.1 BACKGROUND

The Swedish Geotechnical Institute (SGI) and the Swedish National Road Administration (SNRA) arranged in November 1993 a seminar on "Soil Mechanics and Foundation Engineering for Roads and Bridges". The objective was to identify mutual research needs and stimulate co-operation between European countries. Participants from nine European countries representing various research organizations, research councils and governmental authorities met for two days in Sigtuna, Sweden.

The meeting was prepared by an Organizing Committee consisting of Dr *Jan Hartlén*, SGI, chairman, Mr *Bengt Rydell*, SGI, secretary, Mr *Leif Petterson*, SNRA, and Ms *Eva Ekstrand*, SNRA.

1.2 DISCUSSED TOPICS

The following topics were decided to be discussed in plenary sessions and group discussions at the seminar:

- *Geotechnical design*
- *Foundation engineering*
- *Environmental geotechnics*

"Control and quality assurance" was discussed in one of the group discussions. An additional plenary session was held for discussions on "Dissemination and use of geotechnical knowledge".

1.3 PARTICIPANTS

Participants for the seminar were selected on the basis of their interest and expertise in the selected topics. A total of about 30 participants, including the organizers, attended the seminar; see Appendix 2.

1.4 PROGRAMME

1.4.1 Plenary sessions

The participants were requested to write a document, a National Report, describing ongoing and planned research in each country related to the selected topics. These documents were distributed to the chairmen of the plenary sessions for the preparation of a summary report before the meeting. The National Reports and summary reports were compiled and distributed to the participants at the beginning of the seminar.

The first day of the seminar was initiated by opening remarks from the host organizations, followed by three plenary sessions dealing with the seminar topics. During these sessions, each chariman started by presenting his summary report. After that, a series of prepared presentations from different countries was given, related to a specific area of the session topic. These presentions were selected by the session chairman. The presentations were followed by a discussion by the participants and formed the basis for the group discussions the following day.

On the evening of the first day, Professor M Jamiolkowski gave a presentation of the leaning tower of Pisa and the work being done to strengthen its foundations. The presentation was based on the paper "Leaning Tower of Pisa - Updated Information" by Jamiolkowski, Levi, Lancelotta and Pepe. The paper can be found in the SGI Varia 437.

1.4.2 Group discussions

Following the plenary sessions on the first day, two working groups met independently during the second day to explore their topics and compile a summary for a plenary session in the afternoon. Some guidelines were suggested for the discussions in each group, which are presented in Chapter 4. Each group discussed two of the seminar topics respectively.

In a final plenary session the groups presented their results as well as suggestions on potential co-operative research projects, followed by a discussion on how to proceed with there suggestions.

1.4.3 Study tour

On the third day, a study tour was made to some applications of infrastructure projects in Sweden. The study tour included a presentation of the extensive orbital motorways around Stockholm and a visit to some of the important interchanges, which included special earthworks and foundation methods.

1.5 SUMMARY REPORT

This report, edited by the Organizing Committee, contains the reports from the discussions in the working groups together with the papers as submitted by their rapporteurs. The chairman of each session of the seminar has been given an opportunity to revise this report and their views have been included.

The final section highlights the results of the discussions and the suggested potential co-operative research projects among the participating countries are listed.

Chapter 2.
Welcome Addresses

The seminar was inaugurated with welcome addresses given by Mr *Bengt Holmström*, Head of the Road and Traffic Management Division of the Swedish National Road Administration and Dr *Jan Hartlén*, Director General of the Swedish Geotechnical Institute.

2.1 WELCOME ADDRESS - MR BENGT HOLMSTRÖM

Mr Holmström gave a short presentation of the Swedish National Road Administration and the situation of the infrastructure in Sweden today and in the nineties.

Infrastructure investments

Mr Holmström mentioned that during the eighties, increased investment requirements were presented to the politicians. These investments are now taking place during a period of deep recession in Sweden. High unemployment is one of the reasons for the increasing road investments. To build more and faster has in some cases resulted in a demand for two-shift work, thereby reducing the construction time by half.

These large investments during a short time period are a challenge for all geotechnical engineers, not least to ensure no decrease in quality.

As the projects become more and more complicated, quality will become a decisive factor in competition - especially as regards the geotechnical problems.

Functional terms and increased competition

The maintenance of roads is becoming more important. The purchaser will use procurement in functional terms. It will be possible to buy surfacing and drainage systems in one complete job. It will be vital to understand how important it is for the serviceability of surfacings that subgrade, substrate and drainage problems be solved correctly.

Concentration on the infrastructure will also include environmental geotechnics to an increasing extent. Effects on wells and groundwater, contamination of soil and vibrations are examples of areas that will be put into focus.

It was emphasized that improved means for road management, demands for shorter planning and building times, increased competition to increase quality, development of procurement in functional terms, accentuate environmental demands, and approach to EU and the European harmonization work are factors which together will increase the need for road geotechnical research and development.

Geotechnical R&D

One important duty of the Swedish National Road Administration is to participate in research in the geotechnical field. SNRA intends to be a good buyer of geotechnical research and to use the latest models and methods to satisfy the demands on bearing capacity, stability, durability, environmental compatibility, health and safety during use.

New rules and directives, especially EU related ones, will require major adjustments by the Swedish National Road Administration. An increase in co-operation within the EU, through common research and evolution projects between research institutes and authorities, is foreseen by SNRA.

This is one reason for SNRA arranging this road geotechnical seminar together with the Swedish Geotechnical Institute to strengthen co-operation between Sweden and other European countries.

2.2 WELCOME ADDRESS - DR JAN HARTLÉN

In his welcome address Dr Hartlén, the chairman of the seminar, stressed the importance of participating in research in the geotechnical field in order to satisfy the demand for quality and safety. The nineties will be very stimulating for all engineers. A great advantage for Sweden would be to be an EU member, with an increase in co-operation with research institutes and authorities. (The seminar was held before the referendum in Sweden, which decided that Sweden should apply to be an EU member).

It was thus a proper time to see what is going on and how Sweden can approach Europe even more. It was also mentioned that work in the field of soil mechanics was extensive even though Sweden was in a recession. It was also concluded that soil mechanics is becoming broader. One area is the enviromental field -

pollution of soil and groundwater. Another aspect related to the political priorities is to use material and construct roads in a way that would save natural resources. What is going to happen to road materials? Nothing may be dumped, it must be reused and the best material can be used for recycling. There are many matters to attend to.

The government is investing a lot of money in infrastructure, with the result that the work must sometimes be done on two shifts. Thus there may be no time to use ordinary, adapted methods such as vertical drains, and one may ask what techniques we shall have in the future.

This seminar is one step in summarizing research activities in the Nordic area and some European countries. Together we will build a foundation for joint geotechnical research for roads and bridges and by this initiate close and useful cooperation for the European infrastructure.

Chapter 3.
Geotechnical Design

Three main topics of the research on soil mechanics and foundation engineering for roads and bridges had been selected by the Organizing Committee. The first topic was **Geotechnical Design** and for this topic a compilation was made and presented by the chairman of the session. This was based on summaries of the current R&D and research needs in the countries participating in the seminar. These summaries are published in a separate report *"Soil mechanics and foundation engineering R&D for roads and bridges. A summary of activities in the Northern and some Western European countries"* (SGI Varia 437).

The chairman presented a summary and assessment of research needs in the field of geotechnical design. Six presentations were then given by participants from different countries.

Documents and papers used in the presentations are to be found in SGI Varia 437.

3.1 THE CHAIRMAN'S REPORT

Mr Kjell Karlsrud, Norwegian Geotechnical Institute, Norway

The main purpose of this paper was to set the framework for discussions during the seminar, with the overall aim of identifying the most important research and development needs related to the design of roads and bridges.

The first part of the paper summarized and described current and planned research activities in different countries based on information provided by the participants to this seminar. The second part presented the author's more subjective views on overall needs and specific challenges.

It should be emphasized that this paper primarily dealt with design issues, whilst foundation engineering and construction methods were dealt with in a separate session at the seminar.

Review and comments on current/planned R&D

Participants in this seminar provided information about R&D projects from the following organizations:

Sweden	-	Swedish Geotechnical Institute (SGI)
	-	Swedish National Road Administration (SNRA)
	-	Swedish National Rail Administration (SNRAILA)
	-	Chalmers University of Technology (CTH)
	-	Royal Institute of Technology (KTH)
Finland	-	VTT-Road, Traffic and Geotechnical Laboratory
	-	Finnish National Road Administration (FNRA)
Norway	-	Norwegian Public Road Administration (NPRA)
	-	Norwegian Geotechnical Institute (NGI)
United Kingdom	-	Department of Transport (DoT)
	-	Department of the Environment (DoE)
	-	Engineering and Physical Sciences Research Council (EPSRC)
	-	Construction Industry Research and Information Association (CIRIA)
France	-	Laboratoire Central des Ponts et Chaussées (LCPC)
Belgium	-	Ghent University
Italy	-	Studio Geotecnico Italiano (STGI)
	-	Politecnico di Torino

The actual input from these organizations is published in SGI Varia 437. The input may not be complete in the sense that it may not cover all relevant research within the organizations or countries but the information did give an impression of main areas of interest. *Tables 3.1* and *3.2* summarize the number of projects related to various aspects of design and type of road structure. The grouping of projects into such categories was not always obvious. In particular it was difficult to relate projects to specific types of road structure.

In spite of this limitation, *Tables 3.1* and *3.2* do show some systematic differences between defined R&D needs in different countries/regions, as indicated by

Table 3.1. R&D related to type of design aspect.

	DESIGN PARAMETERS						ANALYSES AND DESIGN											CODES AND RELIABILITY		
ORGANISATION	Geophysical Methods	Soundings	In-situ (PM, CPT, DM)	Sampling & Lab-testing	Constitutive Modelling	Other	Settlement	Stability/Bearing Capacity	EP/Ret. Walls	Pile Design	Anchor Design and Reinforced Earth	FEM Modelling and SS Interaction	Ground Water/Seepage	Design of Soil Improvement	Vibrations	Frost	Other	Reliability Methods	Risk Assessment	Limit State Design
SGI						••	••••			•			•							•
SNRA						•	•	•						•					•	•
SNRAILA								•												•
Chalmers								••		•	•	•		••				•		
KTH		•	•								(•)			••	•					
VTT	•		•	•		••	•			•••						••				
FNRA																				
NPRA		•								•					•					
NGI	••		••	••				(•)			•	•						•		
UK			•••	•••	•••••	•••	••	•	•	•		•••••	••	•				•		
LCPC	•	•	•	••••	••	••••	•	•	•	•	••	••		•			•	•		••
GHENT	•		••		•					••										

Table 3.2. R&D related to type of structure.

	ROAD EMB.	APPROACH EMB.	BRIDGES	CUTS AND RET.	CUT-AND-COVER	TUNNELS
SGI	•••		••	•		
SMRA						
SNRAILA	•	•				
Chalmers			•	•••		••
KTH	(•)		•			
VTT	••		•••			•
FNRA	•(•)	••	••	(•)		•
NPRA			••		•	
NGI				•	•	•••••
UK	•		•	••••••		
LCPC	•	•	••	••		•••
GHENT			•			•
STGI			x		x	

the following examples:

- There seems to be a larger interest in tunnelling in Norway, France and Italy than in Sweden and Finland.
- In Sweden there is a great deal of interest in road embankments on soft clays.
- Main efforts continue to lie in the more basic areas of constitutive modelling and numerical methods in the UK.

As a general observation the chairman sensed that research in each country/ organization is considerably influenced by:

- Obviously, local geological and topographical conditions.
- How research is organized and financed.

However, to take a more critical view, one may consider whether or not the following provocative statements express an element of truth:

- We spread our research money on too many and small projects.
- We tend to look for small improvements step by step rather than for breaking barriers.
- Our research is self-propelling, we keep following the same track for too long (lack of an "enough is enough" attitude).
- We focus too little and adapt too slowly to the user's (society's) needs.

General assessment of main challenges

From the user's and society's point of view, the following trends may have an impact on our R&D needs in general.

a) Roads should be as straight as possible

The demand originates partly from the fact that "the fastest route and shortest distance between two points is a straight line". In addition to being a matter of convenience, this is, for society, also a matter of transportation costs, energy consumption, pollution and road safety. The consequences for the challenges and problems we are faced with in road design include:

- Higher road embankments across valleys, erosion gullies, etc.
- Deeper and larger road cuts into hills and natural slopes.
- Road construction across soft and difficult ground that one would otherwise try to avoid.
- More, longer and larger-span bridges and across areas with more difficult topography and accessibility.
- Increased use of tunnels and in more difficult ground conditions (e.g. soils and poor rock).

b) Growing environmental concerns and restrictions
This pertains to, and influences, many aspects of future road design such as:

- To limit environmental impact such as intrusion, noise and pollution, there is a growing demand to use underground space (tunnels, cut-and-cover).
- There is a trend for more severe limits on acceptable vibration caused by road traffic. This is primarily a problem associated with roads on soft ground, and railways. The implications are the need for e.g. smoother roads (less differential settlement) and/or the adoption of special measures to reduce the transfer of vibrations through the ground.
- There are also more severe restrictions on acceptable noise and vibration during the construction phase itself. Some implications are, for instance, less use of driven piles, sheet pile walls and pneumatic equipment.
- The direct or indirect influence of road construction on the landscape, vegetation and groundwater must be minimized. This also calls for increased use of tunnels, "small space" solutions for cuts and embankments, new and better surface protection of cuts and slopes which allows rapid re-vegetation, limited drainage/leakage into cuts and tunnels.
- Roads are more and more frequently built through ground that is contaminated, which requires care to prevent further spreading of contamination as well as caution for workers health and safety.

- Needs for methods/systems to rapidly clean up and/or prevent contamination of groundwater in the event of petrol or oil spills.

Another approach to an overall assessment of R&D needs is to consider the following questions:

- What are the major "problem causes" of direct failures and/or which lead to high maintenance costs for the final product?

- What design aspects are associated with the lowest reliability or highest uncertainty? In other words, where is the largest potential for improvement and reduced costs of the final product? This should be looked at both in relation to determination of design parameters and methods for analysis and design.

- What are the major total cost elements in future road projects?

It may be hoped that this type of perspective on our R&D needs can help to sort out the more specific needs.

Discussion on some specified desin issues

When seen in an overall European perspective, the reporter felt that the major challenges in the future will be related to road tunnels in soils and soft rocks. Tunnels in soils are the most costly road structures we can build, with a typical cost ranging from about SEK 200,000 to 500,000 per meter for a single two-lane tunnel. By way of contrast, the cost of simple tunnels in competent rock are about 15 % of this. Deep road cuts in unstable slopes may also involve fairly large costs, of the order SEK 20,000 to 50,000 per metre for a 10 metre deep vertical cut. The typical cost of bridges is from SEK 150,000 to 200,000 per metre, of which the foundation costs may be 5 to 15 %.

As a starting point for discussions in the seminar, the reporter had also prepared a "short list" of 20 specific research topics, briefly outlined below. This list includes several topics received from the participants, but also some new ones.

Topics related to design parameters

- Further development of geophysical techniques (Georadar, SASW, crosshole seismics) coupled with advanced data processing to provide meaningful user friendly results in an expendient manner, specially geared towards tunnelling projects, dense or coarse soils that are difficult or costly to investigate by other means, and detection of anomalies in the ground.

- How to minimize sample disturbance effects and/or development of correction procedures.

- Establishment of more direct correlations between parameters measured in in-situ tests (CPT(U), DMT, PMT) and excellent field tests or performance data.

- Establishment of unified constitutive models for clays, sand/gravels and silts, which parameters can be determined from relatively few simple tests and/or in-situ tests.

Topics related to numerical analysis and design

- Development of a consolidation model that properly accounts for volumetric creep effects in highly plastic clays or organic soils.

- Modelling of interaction between (reinforced) embankments and soft clay foundations improved by deep cement/lime mixing.

- Design of driven piles in non-cohesieve soils, including set-up effects.

- Buckling resistance of solid steel piles in very soft clays.

- Numerical modelling and design of pile foundations accounting for complex load combinations and pile/bridge interaction.

- Design of bridge foundations installed offshore using suction and/or jetting.

- Design of long high-capacity anchors in rock.

- Design of ground anchors in soils.

- Design of retaining walls with multiple anchors in soils.

- Development of a general user-friendly FEM-continuum model for design of excavations. Compare results with simple beams on Winkler spring-type models.

- Determination of extreme design pore pressure conditions in natural slopes and cuts.

- Modelling and design of soil nailing systems for slopes and cuts.

- Numerical modelling and design of temporary and permanent support of tunnels in soils or poor rock.

- Modelling the effects of grouting on leakage into tunnels and tunnel stability.

- Vibration aspects in road design.

Codes and reliability issues

- Critical assessment of the potential of statistical and reliability based methods for the design of road structures.

As a final remark, the reporter stressed that the above should be taken as the chairman's subjective and preliminary views. Furthermore, the discussions during the seminar will identify the major R&D needs our profession is faced with in relation to roads and bridges.

This will also help in establishing closer ties and cooperation between research bodies in the different countries.

Discussion

In the discussion that followed Prof *M Jamiolkowski* raised the question of the main problems related to infrastructure design and the priority between embankment and environmental problems.

Mr *K Karlsrud* replied that selected targets are the traffic and transport situation in cities and increased bearing capacity of existing roads. In 1993, the R&D included SEK 105 millions, of which 50 % was for selected targets and 10 % for environmental problems.

The importance of using existing knowledge was mentioned. There is an information and time problem and a distance between researchers and practitioners.

3.2 PRESENTATIONS

"Calibration of in-situ testing"

Mr Richard Driscoll, Building Research Establishment, Great Britain

The U.K. has adopted a policy of developing 'national' test-bed sites on different, major geological conditions. On these sites, a wide variety of ground parameter measurements are made, ranging from sampling and laboratory testing through to in-situ tests on 865 mm plates, loaded vertically.

The sites are generally chosen so that parameters from the suite of tests may be used to make class B predictions of the performance of prototype and full-scale foundations. The attached *Table 3.3* shows a comprehensive list of the various sites, their geophysical types, the foundation tests performed and the in-situ tests performed at the sites. Mr R Driscoll showed a short series of slides illustrating examples from the table.

The construction of a cell, based on the vibrating-wire strain gauge, measuring the axial force in a 2.5 m diameter, drilled and cast-in-place concrete pile in London clay; in-situ determination of s_u was calibrated to back analysis of the pile load.

Lateral and vertical load testing of a group of three instrumented, prototype piles in London clay. Dilatometer test measurements of σ'_{hc} were calibrated against pile-shaft shear stresses, $_s$ and were used to develop p-y profiles for the computation of lateral pile displacements; these were calibrated against observations.

In another case, an electro-level, tilt gauge developed by the BRE was used and attached to a full-scale H section steel pile installed in a medium dense sand in Northern France. The pile was subjected to lateral load and electro-level measurements of tilt used to derive displacements, bending movents, shear forces and ground reaction. Subsequent CPT and DMT tests were performed for calibration purposes.

The last example showed a large circular tank load test on chalk in eastern England. Large, 865 diameter plate tests, SPT, seismic cone, surface wave geophysics and other tests were then calibrated against tank settlements.

Building on fill is a problem. It has been estimated that as much as 40 % of current U.K. building construction takes place on recycled land, and many high-

Table 3.3. Sites for in situ-test calibrations.

Test-bed site	Stiff clay			Soft clay			Sand	Chalk				Clayey silt
	London	Gault	Glacial Till	Bothkennar	France	Dartford	France	Munford	A505	LHR	PSG	Pentre
Foundation test: (FS - full-scale;) (PT - prototype)	Pile-lateral^{PT} Pile-vertical$^{PT;FS}$ Raft^{PT}	Pile-vertical^{PT}	Pile-vertical^{PT} (cyclic) Pile-lateral^{PT}	Pads^{FS} Pile-vertical$^{PT;FS}$ Road^{FS}	Embankments^{FS} Pile-vertical^{PT}	Embankment^{FS} Pads^{FS}	Pile-lateral^{FS} Pile-vertical$^{FS;PT}$ Pads^{FS}	Raft (tank)^{FS}	Pile-vertical^{FS} Pads^{FS}	Bridge abutment (gravity)	Bridge abutment (piles)	Pile-vertical^{PT,FS}
In situ tests: (see key)	CPTU; DMT; SBPM; MPM; Plate (865 mm ϕ) DP; GeoP; SPLT	MPM; SBPM; PIP; SPLT; DP CPTU; GeoP	CPTU; DMT; SBPM; PIP; SPLT; MPM; GeoP; Plate (865 mm ϕ)	CPTU; DMT; SBPM; DP; GeoP; FDCP; VT	DMT; MPM; CPTU; GeoP	DMT; VT; DP; CPTU; GeoP.	CPT; DMT; DP; MPM; GeoP.	Plate (865mm ϕ) CPT; DP; GeoP.	Plate (865mm ϕ) CPT; GeoP; SPT	SPT; Plate (865mm); CPTU; Geop.	SPT	DMT; CPTU; VT; SBPM; DP; GeoP.

KEY:
- CPTU - Piezo-cone penetration test;
- DMT - Marchetti dilatometer;
- SBPM - Self-boring pressuremeter;
- MPM - Menard pressuremeter;
- PIP - Push-in pressuremeter;
- DP - Dynamic penetrometer;
- GeoP - Rayleigh wave geophysics / Seismic cone;
- SPLT - Screw plate;
- VT - Vane test;
- FDCP - Full-displacement cone pressuremeter;
- SPT - Standard penetration test.

ways cross such land. The treatment of loose fills is, therefore, important and the BRE has used dynamic penetration and SASW geophysics particularly, to assess the need for and effectiveness of techniques such as rapid impact compaction. Both probing and geophysical test results are calibrated against zone loading trials using refuse disposal skips filled with sand or other ballast.

"Analysis of settlement on soft clays"

Mr Rolf Larsson, Swedish Geotechnical Institute, Sweden

SGI has established test fields in soft clays for settlement observations since the fifties. Test embankments have been instrumented and data collected for a long time. Joint projects between SGI and the Swedish National Road Administration have been carried out.

The method for development is based on
- observed behaviour in the field,
- observed behaviour in the laboratory,
- calculation methods and
- methods for predicting settlements.

Experience from the studies is documented in "Consolidation of soft soil" (SGI Report No 29). There has also been a further development of the CONMULT calculation program , originally developed by the LCPC, in order to make it available for routine applications. The result is a new calculation program, EMBANKCO, for making settlement calculations that include creep settlements. The principle of the program is shown in *Figure 3.1*.

The purpose of the present development is to obtain a better prediction of settlements across road embankments and the settlement development with time. The methods to be used incorporate two-dimensional water flow and coupled horizontal deformations.

"Quality control of deep ground improvement"

Mr Hans Rathmayer, Technical Research Centre of Finland, Finland

The dry mixing lime column method was developed 1967 in Sweden. Originally unslaked lime was used as the stabilizing agent. Development work has been carried out in Sweden by SGI, KTH, Cementa, BPA, CTH, in Finland by VTT,

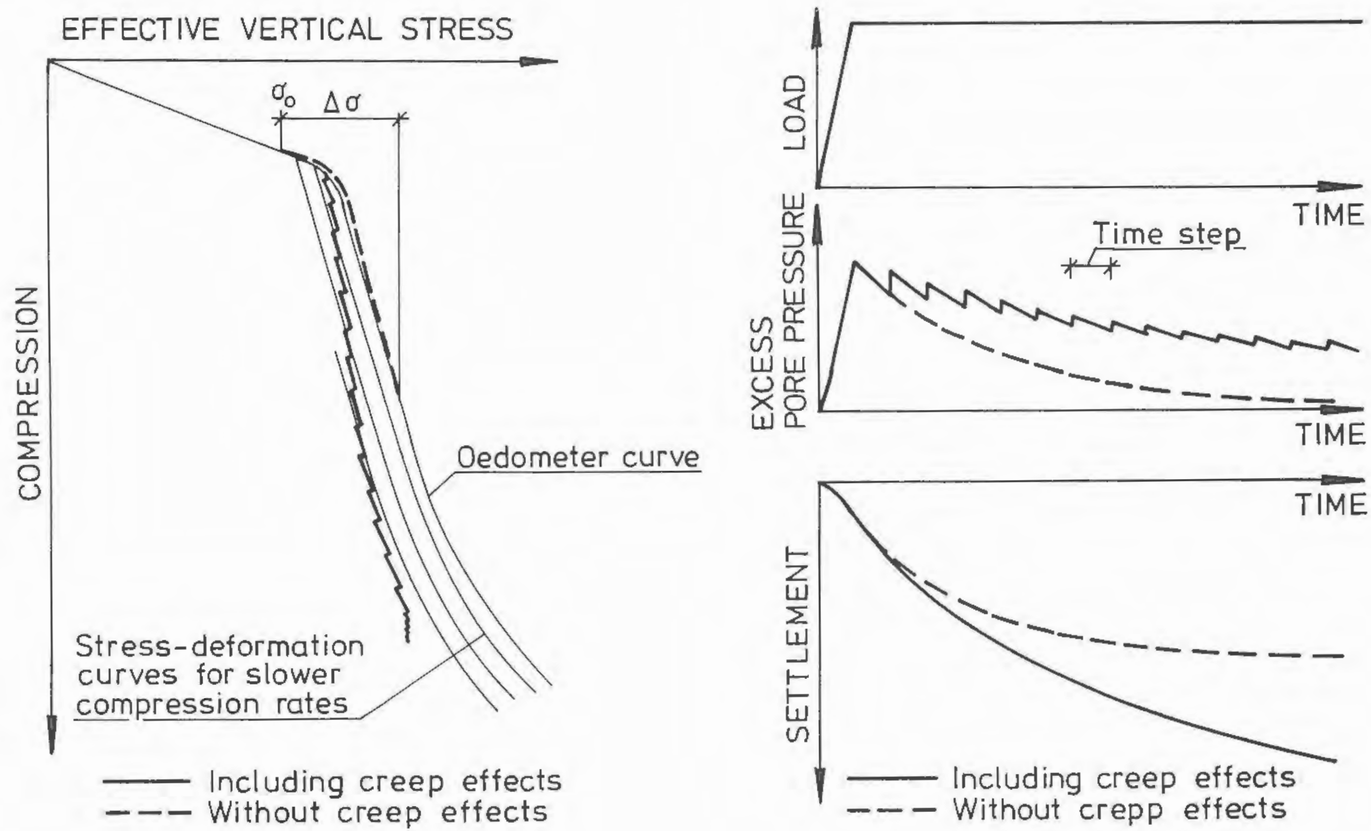

Figure 3.1. Principle for the EMBANKCO program.

etc. Several tools have been developed for quality control of lime-stabilized columns, that are normally not usable for stiffer columns.

There is a lack of standardization of pre-testing procedures (difficult to compare one test with another). The mixing tool is nearly unchanged since the early seventies, but some modifications have been studied. New stabilizing agents are in use such as cement, by-products, fly ash, etc. In the last years, columns with increased strength have been used. However, there are problems with the in-situ tools for checking the quality of the columns because of the usual form of field testing failure and excessive scatter of results. Other methods must be used such as core drilling and testing of core samples in laboratory.

A conclusion is that the designer cannot rely on the quality of deep stabilization. This must be improved.

In the **discussion** that followed Mr *G Holm* mentioned that there is a development in Sweden concerning control methods. Different types of probes and drilling techniques are used.

Dr *L Jendeby* stressed the fact that we do not know how to verify the strength of stabilized vertical cuts, despite the use of the lime-column method for 20 years. Today we install five times as many columns as before. Mr *G Holm* added that in comparison between the Japanese and Swedish methods, the Japanese also have the same scatter as we do in laboratory and field investigations.

Prof *R Massarsch* pointed out that lime columns are different from stone columns, for instance. We need to do some field tests. The Japanese way of making lime columns may not be applicable for Europe.

"Distribution of vertical particle motion with depth for two surface waves of different wavelengths"

Dr ir Wim Haegeman, Ghent University, Belgium

The presentation was based on the paper "In situ characterisation of deformation behaviour of soils and pavements by spectral analysis of surface waves" by Prof ir WF van Impe and Dr ir Wim Haegeman. The paper can be found in SGI Varia 437.

The Spectral-Analysis-of Surface-Wavess (SASW) , method is an in-situ, seismic metod for determining the shear velocity (or shear modulus and Young's modulus) profile of soil and pavement sites. Field measurements are made of surface wave dispersion at a site. This dispersion is expressed in terms of a dispersion curve which is a plot of the propagation velocity versus wavelength. Once the field dispersion curve has been determined, it is used to calculate the stiffness profile at the site using an inversion algorithm. Inversion allows detailed profiles of shear wave velocity to be determined at sites with very simple to very complex stiffness profiles.

The general configuration of the testing procedure is shown in *Figure 3.2*. Surface waves are generated by applying a dynamic vertical load to the ground surface. The propagation of these waves along the surface is monitored using two receivers placed at two distances from the source. In the analysis procedure, the time histories are recorded for each source/receiver spacing and transformed into the frequency domain, resulting in the linear spectra of the two signals. The cross power spectrum of the signals is then calculated and, in addition, the coherence function and auto power spectrum of each signal are calculated.

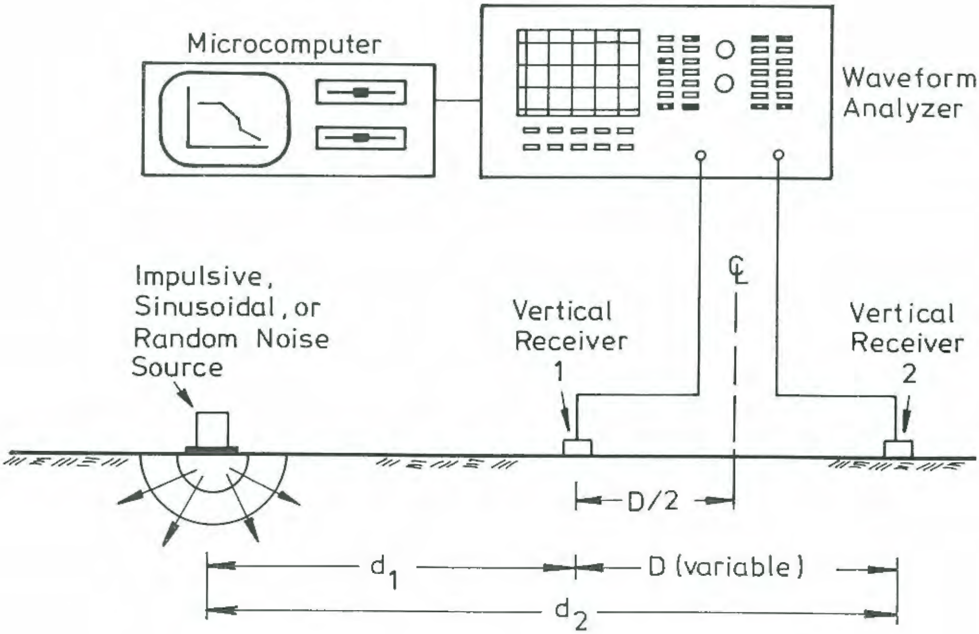

Figure 3.2. The SASW source-receiver configuration.

Dr W Haegeman showed some examples of the SASW method for fast determination of deformation characteristics and integrity testing of members in the field. The method could also be used for measurements on municipal waste disposals to get an idea on the density of the waste. SASW-tests have also been used to investigate the compaction of gravel beds.

In the **discussion** Mr *R Driscoll* mentioned that similar work is going on in the U.K. The problems concern how to input sufficient energy at very low frequencies.

Prof *R Massarsch* focused on the energy progress in layers and the fact that wavelengths do not correspond to depth, there is no correlation.

Dr *W Haegeman* stated that definition of the wavelength is the whole theory of the dispersion problem.

Prof *M Jamiolkowski* mentioned that surface wave tests have been performed down to a depth of 60 metres to find gravel.

"Design of large-span culverts"

Mr Tor Erik Frydenlund, Norwegian Public Roads Adminstration, Norway

In Norway, several long-span flexible steel culverts have been constructed in the past decade. Mr Frydenlund described such culverts and the design philosophy.

Loads are carried through ring-compression (axial force) in the culvert wall. The axial force P can be calculated from

$$P = 1/2\, \gamma\, D\, (H+0.2R) + S_{vn}\, (H+R)^2$$

where γ = soil unit load in kN/m^3
S_{vn} = negative friction number (after Janbu 1976), taken from the graphs in *Figure 3.3a*.

The other symbols are shown in *Figure 3.3b*.

Negative arching occurs for the structure as a whole. The roughness number, R, has a greater influence on the axial force than the mobilized shear strength of the soil.

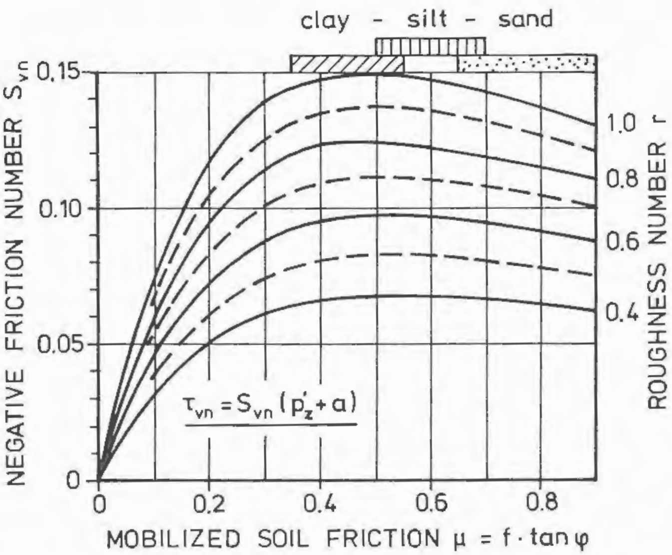

Figure 3.3a. Negative friction number S_{vn}. (After Janbu, 1976)

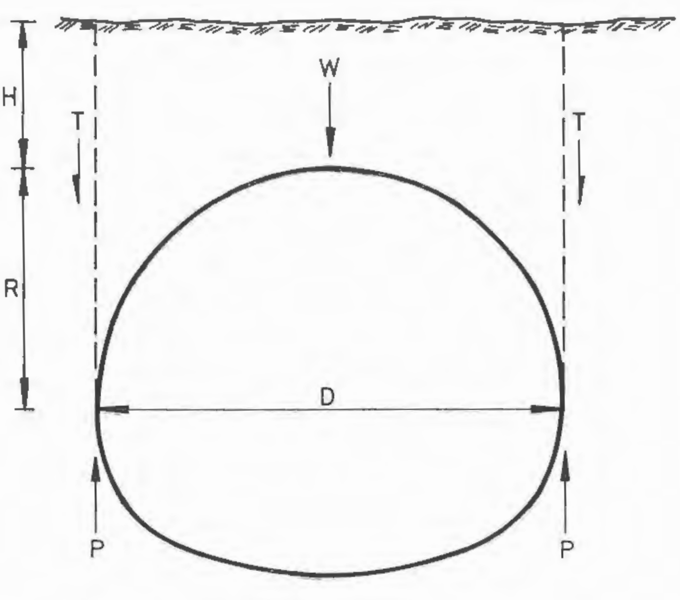

Figure 3.3b. Symbols of large-span culverts.

Buckling need not be considered when the large-span structure is backfilled with soils meeting the minimum level of quality stipulated in specifications. However, supervising the backfilling operations is of outstanding importance.

The calculated and measured thrust forces in the large-span structure are illustrated in *Table 3.4*.

Table 3.4. Calculated and measured thrust force in the long-span structure.

Method		Thrust force [kN/m]
Ring compression		497
AISI and AASHTO		588
OHBDC		353
SCI		865
Leonards		534
Proposed method (R = 0.8)		605
Measured	End of construction	498
	Max. observed	860

References:
Jan Vaslestad: "Soil structure interaction of buried culverts", Dr.ing.thesis, The Norwegian Institute of Technology (NTH) 1990 (In Norwegian).

Jan Vaslestad: "Stål- og betongelementer i lösmassetunneler". Publikasjon nr 69.Veglaboratoriet (Norwegian Road Research Laboratory), Vegdirektoratet (Norwegian Public Roads Administration) 1993.

"Soil nailing design - French practice"

Professor Jean-Pierre Magnan, Laboratoire Central des Ponts et Chaussées, France

The reinforcement of soil slopes by nailing has gained increased popularity in France and in other countries during the eighties. The first nailed wall was built near Versailles in 1972/1973. It was a temporary retaining structure, consisting of a large number of short bars, driven into the soil and then grouted. Since then, two different techniques have been developed, one with short bars driven into the soil and the other one with longer bars inserted into bored holes and then grouted.

The present methods of designing nailed structures in France result from a "National Research Programme" CLOUTERRE, which was run from 1986 to 1990, under the scientific co-ordination of Prof Schlosser, and produced recommendations published in 1991 by the "Presses de l'Ecole Nationale des Ponts et Chaussées" under the title "Recommandations CLOUTERRE 1991", which were later translated into English in co-operation with the United States Federal Highway Administration (1993).

The design of nailed slopes and walls was defined in a way similar to that of Eurocode 7, with a reference to limit states (ultimate and serviceability limit states), using partial safety factors on the loads and soil resistance. Yet, in fact, the only calculations made in practice are those relative to the ULS, because no satisfactory method is available for the prediction of the soil and nail deformations. The design of soil nailing comprises three successive steps:

- First, a computer program checks the stability of the whole nailed mass, with respect to potential slip surfaces, including additional resistance attributed to the nails. The worst conditions with respect to the overall stability of the wall are determined using this procedure;
- In the second step, the nail itself is dimensioned, taking into account its necessary contribution to the overall stability, the conditions of contact at the soil-nail interface and assumptions concerning the stress state at the point of contact of the nail with the facing;
- Thirdly, the facing is designed, usually on the basis of previous experience.

Though no calculation method was felt satisfactory for the prediction of the deformations, experience provides typical estimates of the vertical and horizontal displacements of nailed masses in the case of vertical walls : The horizontal and vertical movements of the top of the wall are found to be equal to one to three thousandths of the wall height.

Research on soil nailing is still going on in France and a second National Research Project (CLOUTERRE II) was launched in 1993. It covers in particular such aspects of the behaviour and design of nailed slopes as their resistance to seismic loads or to frost conditions.

In the **discussion** Mr *B Paulsson* asked if there were any problems associated with installing the nails into the soil. Prof *Magnan* answered that the nails are not very long, about 2 m.

Mr *U Bergdahl* asked if there were any frost problems and Prof *Magnan* replied that so far frost problems are not being dealt with very much. The technique will be improved and the research is now going on. Mr *T Frydenlund* mentioned that in the first soil nailing project in Norway in Lillehammer, insulation material was installed in front of the nails.

On a question from Mr *K Karlsrud* concerning the design calculations, Prof *Magnan* said that the calculations are computerized.

Mr *Karlsrud* raised the question regarding comparison to an anchored wall, where there are main differences in the ordinary design concept. What is the benefit of the nailing system compared to the anchored system? Prof *Magnan* answered that nails are much cheaper. In some cases, the solution could be combining nails and anchors. We are, however, not able to make stability checks. Some installations are made using a nail gun.

Mr Bergdahl asked about the stress distribution over the front cover. Prof *Magnan* answered that during the first research programme, there were plans to make measurement of stresses and movements on the concrete cover, but they were unsuccessful. In most cases, it is not possible to make measurements. This problem will be taken up in the second research programme, e.g. making experiments under artificial conditions.

Chapter 4.

Foundation Engineering

The second topic was **Foundation Engineering** and for this a compilation was made and presented by the chariman of the session. The compilation was based on summaries of the current R&D needs in the countries participating in the seminar. These summaries are published in the report SGI Varia 437.

This session contained an introduction by the chairman and five presentations of different problems in foundation engineering. These presentations gave a picture of present knowledge but also the needs of further R&D. Documents and papers used in the presentations are to be found in SGI Varia 437.

The final discussion on the topics presented, together with the introduction, was postponed to the following group discussions.

4.1 THE CHAIRMAN'S REPORT

Prof Niels Foged, Danish Geotechnical Institute, Denmark

In the introduction Dr Foged mentioned three main topics:

- R&D contributors
- R&D projects
- R&D funding

The first two topics were mainly discussed during plenary session 1. Additional information is given in the summary of on-going and planned research in the participating countries, shown in *Table 4.1*.

For the later discussion Prof Foged raised the main questions:

- How do we provide funds?
- How do we influence:
  - clients?
  - consultants?
  - contractors?

- politicians?
- society?

It is very important for research institutes and organizations, that the above decision makers do see R&D as important for their activities and problems and therefore valuable to initiate and fund.

Some statements for consideration in the group discussions to come:

- Much R&D takes place outside the universities.
- Commercial funding is at present financiug a major part of R&D activities.
- Institutions with substantial governmental support are in a much better situation to apply for funding with self-financing claims, e.g. EU-funding.

Clients often raise the questions:

- Is this R&D "something nice to know"
  or "something we need to know"?
- How can I save money?!

We must use this commercial background as well as the technical content of the R&D projects in our way of marketing advanced geotechnical investigations and competiting for R&D funding.

Finally, quality assurance was addressed with the provocative statements:

- Quality management systems assure you get what you pay for!
- Quality improvement policies secure raised standards and knowledge!

Table 4.1. Foundation Engineering. Summary on on-going and future research projects.

Place	Activity
1. Laboratoire Central des Ponts et Chaussées, France	GEO 29: Durability of geotextiles and behaviour of reinforced structures
	GEO 30: Widening of road embankments
	GEO 31: Side effects and behaviour of structures under seismic loading
	Technical committee CT 22 on Road geotechnical engineering: • Recommendations and codes practice

Technical committee CT 24 on Soil and rock mechanics and foundation engineering

- Limit state analysis and design
- Embankments on soft soils
- Soil improvement
- Lightweight fills
- Foundations on rock
- Retaining structures
- Tunnels
- Foundations (groups of root-piles, new design methods)

Co-operative research
(EU and other international research projects)

SPRINT

- Quality control for geotechnical testing

EUREKA

- PREMEC: Use of the mechanical pre-cutting method for tunnelling in hard and soft water rocks

France-Portugal

- Behaviour of geotextile-reinforced structures

France-Germany

- Behaviour of a geotextile-reinforced retaining wall
- Tunnelling

France-Greece

- Foundation design and slope stability

National projects

CLOUTERRE

- Full-scale and laboratory experiments on soil nailing

CLOUTERRE II

- Monitoring of the displacement of nailed walls
- Behaviour of nailed structures under static and dynamic loading

FOREVER

- Behaviour of micro-piles

2. Swedish National Rail Administration, Sweden

Interaction track-bridge-foundation-soil

Stability of railway embankment under dynamic train load

Design of catenary support footing

Eurocode 7

Future projects
- Design models for soil reinforcement
- Lime/cement columns
- Statistical methods for foundation sturctural design
- Development of analytical methods for calculation of settlements for embankments and footings
- Requirements for overall stability for existing roads including a method for locating roads with low stability

3. Finnish National Road Administration, Finland

TPPT-Road Structures Research Programme
- Structural performance (fatigue, resistance to frost, heat and geotechnical bearing capacity)

4. Swedish Geotechnical Institute, Sweden

Ongoing projects
- Follow-up system for settlement in road embankment on fine-grained soil
- Settlement follow-up of Main road No. 50 in Sweden
- Settlement follow-up of European highway E6.
- Foamed concrete in ground, road and railway constructin
- Soil improvement: Improvement of design methods. Settlement calculation for lime column improvement
- Prediction and performance of reinforced soil as retaining structures
- Follow-up of settlements of bridges
- The use of cement and cement-lime in deep stabilisation of soft soils
- Lime-cement columns, textbook on design, performance and inspection

Planned activities
- Consequences of foundation works for buildings
- Development of regulations for material testing and design of soil reinforcement
- Ground water in excavations
- Application inventory of new, international methods for soil improvement
- Settlement follow-up of lime/cement columns improvement for railway embankments

5. Chalmers University of Technology, Sweden

Ongoing projects
- Friction piles in sand
- Load-deformation behaviour of expander-body piles in sand
- Reduction of vertical stresses on rigid pipes by the use of soft inclusions under the invert
- Integrity control of lime/cement columns
- Soil nailing
- Tunnelling in soil and hard rock

6. Ghent University, Belgium

Ongoing projects
- In situ characterization of deformation behaviour of soils and pavements by spectra-analysis of surface-waves
- Dilatancy effects in stone columns

7. Royal Institute of Technology, Sweden

Ongoing projects
- Vibratory pile driving
- Soil compaction using vibratory probes (MRC compaction)
- Lime and lime/cement columns

8. Delft Geotchnics, Holland

Ongoing projects
- Geomechanics of peat (Analysis of factors determining the safe performance of embankments on peaty soils during construction and maintenance)
- Tunnelling in soft soil
- Probabilistic design guidelines and standards

9. VTT, Finland

Ongoing projects
- Bearing capacity of piles
- Foundation of scaffolding
- Problems in infrastructure related to soil, rock and ground water

10. Politecnico di Torino, Italy

Ongoing Projects related to actual and planned bridge construction project

11. Norwegian Geotechnical Institute, Norway

Ongoing projects
- Long-term monitoring on reinforced earth test fill
- Verification testing of deep cement/lime mixed columns
- Microtunnelling methods and their applicability
- Tunnelling in soils
- Updating of NGI's Q-classification systems for rocks and design of tunnel support
- State-of-the-art documentation of Norwegian sprayed concrete technology in relation to rock tunnelling
- Direct use of in situ tests for design of piles and shallow foundations

12. Norwegian Public Road Administration, Norway

Ongoing projects
- Tension leg anchoring
- Load distribution in pile groups
- Reinforced earth structures
- Thin-walled superspan culverts
- Superlight filling materials

13. United Kingdom

Ongoing projects

Deep and shallow foundations
- Behaviour of piled foundations under lateral loading
- Pile testing
- Economics of alternative construction methods for accommodating soil induced lateral loading on piled foundations
- Piles in weak rock

- Improved design of embedded retaining structures
- Studies of the behaviour and economics of cohesive backfill
- Behaviour of diaphragm walls during construction
- Behaviour of bored pile retaining structure during construction
- Limit state design of sub-structures and foundations
- Performance of in situ anchored retaining walls
- Instability of foundations on shrinking and swelling clay soils
- Development of methods of assessing collapse compression in fills
- Development of empirical procedures to relate small-scale site tests to observed foundation behaviour
- Monitoring the performance of foundations and the effects of excavation on foundations of buildings
- The long-term settlements of filled ground - monitoring and assessing the consequences for buildings
- Compensation grouting to prevent subsidence due to tunnelling

Soil reinforcement/improvement

- Reinforced/anchored earth construction over mining subsidence and poor foundation conditions
- Long-term performance of geotextiles
- Development of geotextile ground anchors
- Reinforced/anchored earth construction study of new materials and methods
- Monitoring of full-scale reinforced earth structures
- Monitoring of full-scale anchored earth structures
- Re-appraisal of earthwork compaction
- Monitoring of earthwork compaction
- Lime stabilisation
- Ground improvement techniques
- Development of CEN test procedures for geotextiles
- Use of dynamic probing, geophysics and other in-situ tests to assess effectiveness of ground improvement techniques
- Improving the quality assurance procedures for the placement of engineered fills and post-placement fill treatment

4.2 PRESENTATIONS

"Base capacity of bored piles in sand"

Professor Michele Jamiolkowski, Technical University of Turin, Italy:

In his presentation Professor Jamiolkowski focused on mobilization of the ultimative base resistance q_{bcrit} compared to the cone resistance. Full-scale tests of driven and bored piles were compared with the result. The base resistance at failure turned out to be independent of the pile installation. Empirical rules for correlating the bearing capacity based on penetration tests were given and assessments using the theory of elasticity were suggested.

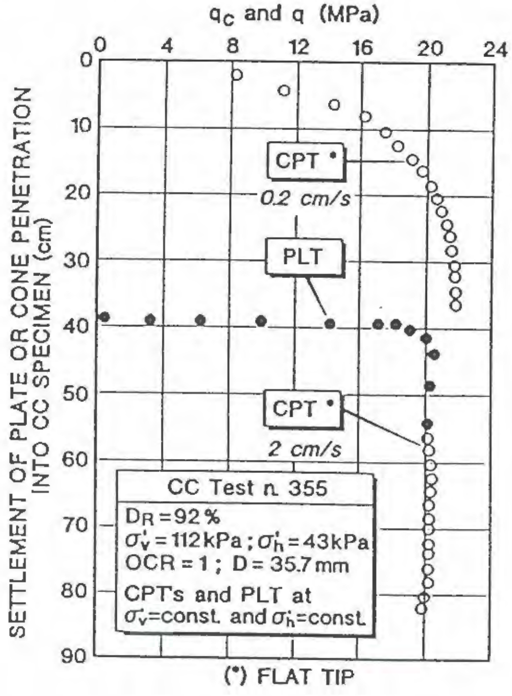

Figure 4.1. Plate loading test versus cone penetration test in very dense Ticino sand.

Reference:

Ghionna, V.N., Jamiolkowski, M., Lancellota, R. and Pedroni, S. (1993): *Base capacity of bored piles in sands from in situ tests*, 2nd International Geotechnical Seminar - Ghent University -Belgium - 1-4 June 1993.

The **discussion** included contributions from *Mr T Frydenlund* on pile group capacity with a statement on having only half the bearing capacity. *Dr S Liedberg* and *Prof R Massarsch* asked how the ejected piles were installed regarding the load tests. *Prof M Jamiolkowski* gave some practical points of view taking into account the shaft friction of larger bored piles.

Mr R Driscoll mentioned the use of base grouting in the U.K. In this matter *Prof M Jamiolkowski* referred to long experience in Italy using different techniques and called for simple procedures.

"Reduction of vertical stresses on rigid pipes by the use of soft inclusions under the invert"

Dr Sven Liedberg, Chalmers University of Technology, Gothenburg, Sweden

Stress concentrations at the invert due to improper bedding are one of the main reasons for bending failures of rigid pipes. Soft inclusions below the invert are shown by full-scale testing and SPIDA finite element modelling to be more favourable than a more traditional placement above the pipe.

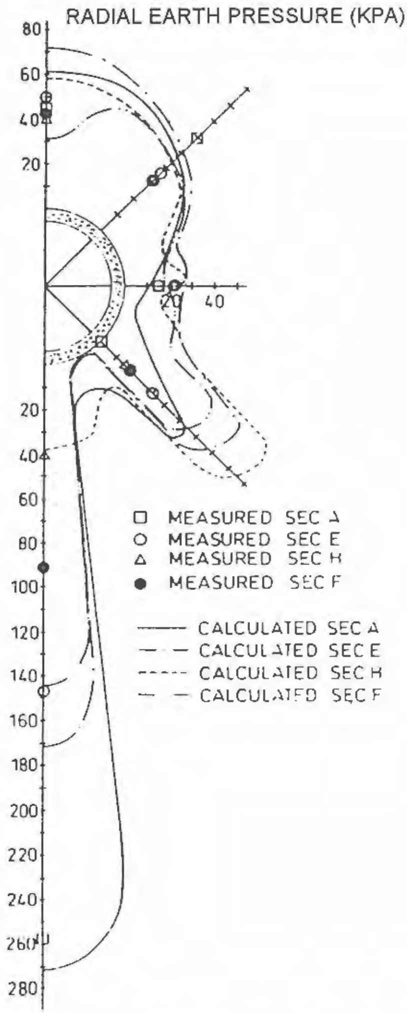

Figure 4.2. Measured and calculated radial earth pressures.

In the **discussion** Mr *T Frydenlund* showed an alternative, a box-shaped cross section with an inclusion 0.5 m above the culvert, claiming it was a cheaper design. Prof *R Massarsch* mentioned the same principle used for bomb shelters with better effect.

Reference:

Liedberg, N.S.D. (1994): *Reduction of vertical stresses on rigid pipes by the use of soft inclusions under the invert*, XIII ICSMFE, 1994, New Delhi, India.

"SGI-SNRA - Research on shallow foundations in cohesionless soils"

Mr Ulf Bergdahl, Swedish Geotechnical Institute, Sweden

The research was started 15 years ago to meet a need for settlement calculations for bridges. Based on many load tests compared with different calculation methods available from literature, an understanding of the bearing capacity was gained. However, the deformation parameters showed large scatter. Based on comparisons between plate load tests and settlement measurements on bridge foundations, it became clear that most of the settlements takes place very close to the foundation level. Furthermore, accurate prediction is difficult since a scatter larger than ± 50 % was obtained for different calculation methods.

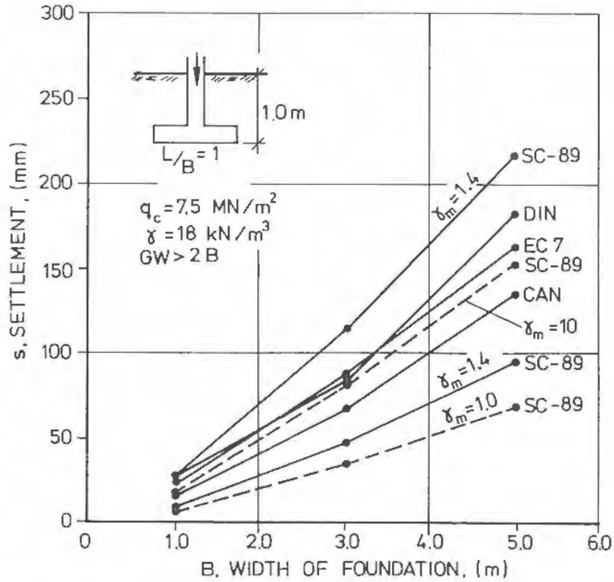

Figure 4.3. Settlement as a function of foundation width.

Experience with the European Code EC7 indicates a need of refine the selection of the partial safety factors. There also seems to be a need for studies of foundations made close to slopes.

In the **discussion** Prof *M Jamiolkowski* asked about the critical bearing capacity of sands, shear stress distribution along failure surfaces, mobilization of shear stress, stress level dependency and isotropy. Mr *Bergdahl* claimed the Eurocode to be conservative in general and mentioned that Swedish experience has caused selection of different calculation factors for depth below ground surface and inclination of the load.

"Swedish Pile Commission - Piling Research in Sweden"

Mr Göran Holm, Swedish Geotechnical Institute, Sweden

The Swedish Pile Commission work is unique and has put into practical use: Basic R&D, investigations of the need for different types of technique, development and information to the practising engineers. The work has been focused on driven precast concrete piles and studies of control during production, installation and pile performance. The members include authorities, contractors, manufacturers and consulting companies. The research has been productive and experience has resulted in new development and research.

The Swedish Pile Commission works with a great number of working groups:

- Friction piles in clay
- Friction piles in silt and sand
- Dynamic testing used in piling including integrity testing and stress wave measurements
- Large diameter steel tube piles
- Corrosion
- Environmental impact
- Design methods
- Piling methods in Europe

"Engineering geological approach to bridge foundations in Denmark - focus on Storebælt"

Dr Niels Foged, Danish Geotechnical Institute, Denmark

In the development of Eurocode EC7, the DGI wants to include engineering geological evaluation as a governing method for selecting soil and rock properties. Experience from three major infrastructure bridge projects at Lille Bælt, Store Bælt and Storstrømmen was described.

The engineering geological section at Lille Bælt contained marine and meltwater deposits resting on till and tertiary clays. Especially the last formation, containing high to very high plastic clay, called for very detailed field and laboratory studies of shear strength, permeability and deformation properties. Even after more than 50 years, settlement of the caissons for the old bridge continues. The engineering geological model has been an effective base for the investigations for the new suspeusion bridge.

At Storstrømmen, the geological section contained postglacial marine sand and mud, peat and solifluction soil, late glacial meltwater clay and sand and glacial clay and sand till. These formations were underlain by glacially reworked lime mud and Senonian chalk. Generally the caissons were founded directly in the Quaternary layers, but, locally, piled foundations were employed. The pylons were carried by piles driven into lime mud (chalk). An illustrative profile of how to make effective use of the geological model for presentation of geotechnical test results was presented and discussed.

The combined railway and motorway bridge over Store Bælt was described. Based on a huge number of seismic profiles, boreholes and in situ testing, an engineering model was established and all geotechnical data were made available to engineers and contractors in the Store Bælt GEOMODEL.

Chapter 5.
Environmental Geotechnics

The third topic at the seminar was **Environmental Geotechnics**. For this topic a compilation was made and presented by the chariman of the session. The compilation was based on summaries of the current R&D and research needs in the countries participating in the seminar. These summaries are published in the report SGI Varia 437.

The session contained an introduction by the chairman, presenting a State of the Art Report, which was included in the documents of the seminar. Six presentations of topics related to the theme of the session were given.

Documents and papers used in the presentations are to be found in SGI Varia 437.

5.1 THE CHAIRMAN'S REPORT

Dr Jan Hartlén, Swedish Geotechnical Institute, Sweden

Background

The importance of environmental issues has increased with each year. In fact, it is said that in the USA, more than half of the engineers in soil mechanics are involved in environment-related problems.

Substantial investments will be made in the infrastructure in the coming years. The reasons are many, such as international co-operation in the EU and counteracting the recession and its consequences on high unemployment. The infrastructure investments in Sweden will be made primarily in very large projects, e.g. a bridge between Sweden and Denmark and highways and railways to form a triangle between Stockholm, Gothenburg and Malmö. Such big projects will have an impact on the environment both during construction and maintenance. To limit these consequences, in the Stockholm area the roads will be placed mainly underground in rock.

An assessment of the environmental impact must be made before new projects will be approved. The types of environmental impact may be many, including

- disturbances from vibrations induced by construction work and traffic
- settlements induced by excavation and groundwater lowering
- use of scarce natural resources such as gravel and sand
- contamination of soil and water in the vicinity of roads

Various measures can be taken to prevent/limit the environmental risk of disturbance, such as

- use of relevant investigation methods to evaluate the soil conditions in detail
- make risk assessments related to predictions on deformations, vibrations and environmental impact
- monitor water pressure changes
- use secondary material
- protect groundwater from contamination under and in the vicinity of roads

Settlements and slope stability are matters related to environmental issues, but these areas will not be dealt with here, as they normally are referred to normal geotechnical design, at least in Sweden.

Vibrations from traffic

Dynamic loading, i.e. from road and railway traffic, gives rise to waves which spread out in the soil. If the soil is modelled as an elastic half-space, four types of waves can be identified; the *compression wave* (or primary wave) that forces the soil particles to oscillate in the direction of the propagating wave, the *shear wave* that makes the soil particles move perpendicular to the propagating wave, and two surface waves - the *Rayleigh wave* and the *Love wave*. The Rayleigh wave exists at any free surface, i.e. the ground surface, while the Love wave needs a special stratification in order to develop. For a vertical vibration source, the Rayleigh wave transfers 67 % of the total vibration energy, the shear wave 26%, and the compression wave 7 %. The assumption of elastic behaviour is appropriate if the shear deformation does not exceed 10^{-3} %, which is often the case for vibrations caused by traffic. Typical shear deformations for different kinds of dynamic loading are given in *Table 5.1*.

Damping properties of the soil make the waves fade out with distance. The Rayleigh wave is the one that can propagate the furthest away from the vibration source.

Table 5.1. Typical shear deformations for different kinds of dynamic loading.

Type of dynamic loading	Shear deformation, γ * (%)
Vibrations from railway traffic	10^{-5} - 10^{-3}
Vibrations from road traffic, blasting, pile driving	10^{-4} - 10^{-2}
Machine foundations	$< 10^{-4}$
Damaged machine foundations	10^{-3} - 10^{-1}
Off shore	10^{-3} - 10^{+1}
Static loading	10^{-3} - 10^{+1}
Earthquakes	10^{-3} - 10^{+1}
Soil compaction	10^{-4} - 10^{+2}

The response of the soil to dynamic loading (e.g. vibrations) can be described using the dynamic amplification factor, M. This factor depends mainly on

- the relation between the frequency of the dynamic loading and the resonance frequency of the system.

- the damping properties of the soil.

The dynamic response of a simple mass-spring-system is based on a simplified model. Even if the model based on a mass and a spring is very simplified, it is possible to see that the amplification factor can be larger than 1.0 when the frequency of the loading is lower than the resonance frequency of the system, and can be smaller than 1.0 when the frequency of the loading is much higher than the resonance frequency of the system.

Therefore, the resonance frequencies of, for example, a railway construction must be so determined that they do not coincide with the frequency of the dynamic loading of the trains. If they do, considerable magnifications of the wave amplitudes could be expected.

Several different methods are available to us for eliminating problems with vibrations from traffic. The railway or road construction itself can be made heavier by using more dense materials; this has been found to reduce the vibrations considerably. Another method is to install lime columns, lime column walls or combinations of these to create stiffer systems. A railway and a road can also be founded on end-bearing piles, resulting in a reduction of vibrations. There are also examples where cushions have been used with promising results.

It may, however, be difficult to determine the resonance frequency of different systems, since phenomena such as reflection and refraction of the waves can create effects that are very difficult to foresee. Problems can occur quite far away from the vibration source.

Examples of on-going projects:

Royal Institute of Technology, Sweden
- Vibrations caused by man-made activities (soil-structure interaction).
- Vibration in soils caused by traffic.

LCPC, France
- Seismic loads and site effects.
- Effects of seismic loading on bridges.

Norwegian Public Roads Adm., Norwegian State Railways, City of Oslo, Norway
- Vibrations from road and rail traffic

National Rail Adm., Sweden
- Vibration prediction, especially in soft clay.

VTT, Finland
- Structural design of noise barriers
- Traffic vibrations (from trains) and the environment.

Saving natural resources

Society is more and more directed towards saving natural resources and the use of a life-cycle approach when using products. This means that the use of secondary materials and re-use of waste materials will be encouraged, as well as re-use of road construction material.

Use of secondary material will result in a reduced need for disposal and in the saving of natural resources. Examples of secondary materials are ashes and slags from energy production (e.g. coal ash) and from industrial processes (e.g. steel slag) as well as excavated fill and dredged material. It must be emphasized that no materials with higher quality than needed should be used.

Several industrial byproducts show beneficial physical properties, such as pozzalanic properties and low density. Most combustion residues have a density only just above 1 t/m^3, which, when used as fill on soft ground, will reduce the need for soil improvement. The pozzalanic activity of coal fly ash has been utilized when making lime-cement columns.

The environmental risk of using byproducts must always be evaluated, as they may contain higher levels of salts and heavy metals than natural aggregates. Systems and standards, including CEN, have now been developed in most European countries to make environmental assessments in a relevant way. Such characterizatiou includes proper sampling, sample preparation and leaching tests. As waste products are formed under variable conditions, a detailed characterization is needed in which effects such as redox and pH dependence must be analysed.

In The Netherlands, a special technique, with relevant test methods, has been developed (Aalbers, 1991). In Denmark a regulation exists and in Germany there are "Merkblätter" for different residues and uses.

<u>Examples of on-going projects:</u>

Finnish Road Adm., Finland
- Increased use of waste materials.

Rijkswaterstaat, Netherlands
- Reduction of the use of natural materials.
- Application of waste material.

SGI, Sweden
- Use of by-products in road embankments.

National Road Adm., Sweden
- Methods for making inventories, describing properties and planning for rock, natural gravel and coarse till resources.

VTT, Finland
- Utilization of bottom ash for stabilization.

Groundwater contamination and protection
Highways are often situated close to groundwater aquifers, because favourable geotechnical and geohydrological conditions for road construction often coincide

with groundwater supplies. In such cases, it is obvious that highways and their traffic constitute a contaminating risk to groundwater aquifers in the neighbourhood. There is also a risk of contaminating surface water nearby.

Contaminated water from the road may be both surface run-off water and possible harmful liquids connected with accidents. The effect of road salting is also discussed in this context. It is difficult to balance the beneficial effects of de-icing roads and the detrimental effects of increasing the chlorine content of the groundwater. In Finland for example, many eskers exhibit high chlorine concentrations due to road salting. The maximum value reported is 290 mg/l.

In the United States there has been a search for road de-icing chemicals to replace common salt. Possible alternatives are CMA [$CaMg(CH_3COO)_4$] or methanol. From CMA experiments it is said: "Avoid CMA use when a high rate of runoff will pass over very coarse soil that overlies a sensitive aquifer (to avoid high acetate mobility in soil with low anion exchange capacity). Tentatively, withhold use of CMA along highway segments that may have relatively high heavy metal concentrations in roadside soils and which are above important aquifers or adjacent to valuable surface water".

Preparatory actions

Areas around groundwater installations are protected. Nearest to the well, the water intake area, activities are allowed just for the water plant. The next zone including the catchment area is often divided into two parts, the inner and outer protection zones. For the inner zone, the restrictions are rigorous, considering that the time is limited to stop liquids leaking from accidents. The restrictions on the outer zone are, consequently, less rigorous.

If highways are allowed through the inner zone, safety devices are needed. The extent and design vary, but for open aquifers the protection is increased closer to the well. For closed aquifers another approach is needed. Groundwater formation may take place far away from the well, where infiltration is possible into permeable soils.

Common preparatory actions include the location of new highways in areas without valuable water plants or areas where natural soils protect the underlying aquifer. Examples of safety devices are railings, smooth "forgiving" ditches, sealing materials in the ditches. Plastic liners (high density polythene, HDPE) or geoliners with bentonite may be used as sealing material. These materials are often better and more practical to handle than natural soils like clay. It is necessary to collect surface run-off water from highways within the protection zone. The water is led to surrounding areas with less sensitive water. Devices for sedimentation and oil-separation are recommended to take care of dangerous chemicals.

Surface and groundwater problems related to highways are certainly being discussed in many countries. Guidelines exist or are under development as follows:

- Finnish National Road Administration, 1991: Groundwater protection along roads.
- Transport Minister of FRG, 1987: Drainage guidelines.
- Swedish National Road Administration, 1982: Surface- and ground water protection. New guidelines are expected in 1994.

<u>On-going projects:</u>

Dep. of Transport, United Kingdom

- Site investigation techniques, environmental factors and investigation of derelict, marginal and polluted soil.

Dep. of the Environment, United Kingdom

- Performance of geotechnical barriers to contaminant flow.

NGI, Norway

- Contamination in saturated and unsaturated zones.
- In-situ remediation of ground contaminated by oil spills.

EPSRC, United Kingdom

- Study of pollutant spillage and electro-kinetic soil remediation.

National Road Adm., Sweden

- Techniques for protection against environmental effects.
- Model for describing effects on water from chemical and physical aspects.

SGI, Sweden

- Water protection in areas along roads.
- Environmental impact on soil in areas along roads.
- Groundwater in modelling as a tool for risk assessment and remediation of contaminated groundwater.
- Durability of geosynthetics.

Treatment of runoff water

There is today undoubtedly sufficient data to indicate that there is a chronic degradation in water quality downstream of major highway storm water outfalls. The need for treatment of the highway runoff is primarily a question of the pollution effect in the local receiving systems.

When the pollutant in question results in an acute or accumulative effect, it has to be considered. If the effect is acute, the runoff water must be treated in order to reduce the impact from the single events. Concerning accumulative effects, it is more important to reduce the total amount of pollutants during a given period.

The most important pollutants to reduce are heavy metals and organics. As they are bound to particles, a reduction in the amount of suspended solids (SS) also reduces the amounts of heavy metals and organics.

Relevant treatment methods for highway runoff are various kinds of natural systems. In most cases this will result in a system that costs less to build and operate than traditional mechanical treatment alternatives. Natural systems for effective runoff treatment are vegetative controls, wet detention basins, wetlands and infiltration basins. All depends on natural physical and chemical processes as well as on the biological components in each process. These measures, used singly or in combination, can provide significant reductions in pollutant loading resulting from highway runoff.

Many of these concepts have long been used for treatment of other waters. For example the use of both natural and constructed wetlands to treat waste water from point sources is relatively well documented, but in the treatment of highway runoff limited information is available. Therefore a number of areas require further research to optimize highway runoff treatment. These include:

- Hydrology and loading effects. What are the long-term effects of variable flows and shock loading on the efficiency of the uptake mechanisms? There are also relatively few studies that have specifically documented the impacts of highway runoff on receiving water quality and biota.
- The optimum properties of water depths, basin geometry and other dimensional criteria to maximize pollutant removal.
- Long-term management strategies. There is still insufficient information on optimization techniques for improving system efficiency and for year-round performance. For a country such as Sweden it is of special interest to obtain knowledge about the influence of the climate on pollution removal.

On-going projects:

SGI, Sweden

- Treatment of highway storm water.

In the **discussion** Prof *J-P Magnan* stated that in the laboratory at LCPC work is being carried out concerning water and water pollution within the field of geotechnical engineering. There are also several on-going research projects, which are directed towards pollution and the protection of sites and the use of waste materials.

Prof *M Jamiolkowski* mentioned that there are important discussions in Italy on how to perform research in environmental engineering. There is a need to approach some kind of formula and to define environmental geotechnics and what is the right course. Another question is how to stabilize hazardous waste.

Dr *J Hartlén* informed that, as a part of the SGI quality system, the laboratory at SGI is accredited for both environmental and soil testing.

5.2 PRESENTATIONS

"Vibrations from roads and railways - acceptable levels in buildings"

Mr Tor Erik Frydenlund, Norwegian Public Roads Administration, Norway

In major parts of the most densely populated areas in Norway the subsoil consists of soft marine clay to great depths. Road and rail traffic passing through such areas may generate and transmit perceptible vibrations far away from the source. Similar conditions exist in Sweden and Finland, but in other parts of Europe to a much lesser extent. In international standard ISO 2631-2, which is also approved as a Norwegian standard NS-ISO 2631-2, rather strict recommendations are given in an appendix to the standard regarding permissible vibration levels in dwellings, office buildings etc. Strict adherence to such levels will limit the possibilities for using areas along roads and railways for building purposes in Norway. It will also create difficulties for establishing new road and rail links through populated areas.

In order to shed light on the particular soil conditions in Norway related to strict vibration levels, the Norwegian Building Research Institute and the Norwegian Geotechnical Institute, have since 1991, been pursuing a common project financed by the Norwegian State Railways, the Public Roads Administration and the municipal tramline company in the City of Oslo. So far four reports have been published. In Report no. 4, dated 1992-12-15, a review of the previous reports and recommendations for permissible vibration levels in buildings is given for projects where the Planning and Building Code applies. As for traffic noise, a distinction is made between a recommended level and a maximum level. Under the conditions prevailing in Norway it is not advisable to apply a non-perceptible vibration level. A common level where resulting vibrations in nearby buildings are perceptible but not disturbing when large vehicles or heavy trains pass by, is therefore recommended.

Max. $a_{w,rms}$ = 11 - 20 mm/s^2 (frequency-weighted rms values)
Max. $v_{w,rms}$ = 0.3 - 0.6 mm/s
(corresponds approx. to (v_{peak} = 0.9 - 1.9 mm/s)

In cases where such conditions cannot be established or costs are prohibitive, a maximum level must be defined. Vibrations may then easily be perceived when large vehicles and heavy trains pass, but will not be experienced as disturbing to most people.

Max. $a_{w,rms}$ = 35 - 50 mm/s^2 (frequency- weighted rms values)
Max. $v_{w,rms}$ = 1 - 1.4 mm/s
(corresponds approx. to v_{peak} = 3.1 - 4.4 mm/s)

Future activities within the project will be evaluated next autumn after having received possible reactions from Norwegian vibration experts and authorities. Contacts have also been made with other Nordic countries, and Swedish experts in particular seem concerned by the recommended vibration levels given in ISO 2631-2. So far, however, interests for a possible Nordic co-operation in this field seems to be limited to establish a common database for vibration data. Such a database may constitute a valuable contribution to establishment of recommendations for permissible vibration levels.

Reference:

Arild Brekke, Christian Madshus: "Grenseverdier for vibrasjoner fra veg og jernbane", Norges FoU-senter for Bygg, Anlegg og Geoteknikk ANS, Rapport nr 4, 1992. (In Norwegian.)

In the **discussion** Prof *J-P Magnan* suggested that a decentrailized system related to the problem could be found, as actual vibration levels in different soils differ. It is a good idea to put information in a data base to permit exchange.

Mr *H Rathmayer* stressed that there is a cost factor - what does it cost to build on a certain area? The environmental aspects should be taken into account and then a good economic solution found. Vibration is only one topic.

"Man-Made Vibrations and Solutions"

Professor Rainer Massarsch, Royal Institute of Technology, Sweden

Prof Massarsch discussed the generation and propagation of man-made vibrations in the ground. The problem can be diveded into two categories. The first concerns small-amplitude vibrations, i.e. the effect on the human environment or on sensitive instruments. Acceptable vibration levels can be very low and may be chosen on a subjective basis. The second category concerns vibration problems which can cause or contribute to the damage of structures.

The main sources of man-made vibrations are traffic, construction activities, vibrating machines from heavy industries and construction activities. *Figure 5.1* shows typical frequency ranges and strain levels for different vibration sources, covering a wide range. It is apparent that these large variations must be taken into consideration when assessing vibration problems.

The main factors which influence the propagation of vibrations in the ground are 1) wave attenuation, 2) vibration focusing and 3) resonance. These phenomena are complex and can, thus, be discussed only in a simplified way.

Finally, Prof Massarsch pointed out that damage to structures from ground vibrations is usually attributed to "dynamic effects", such as vibration amplification and resonance effects in structures. Existing codes and regulations are generally empirical and based on observations of damaged structures. The results of such investigations are strongly affected by the local soil conditions and these criteria are therefore difficult to apply elsewhere.

Vibration problems are all controlled by the following common factors: 1) The dynamic characteristics of the vibration source, 2) the propagation of vibrations in the ground and 3) the effect of ground vibrations on buildings, sensitive installations or human perception.

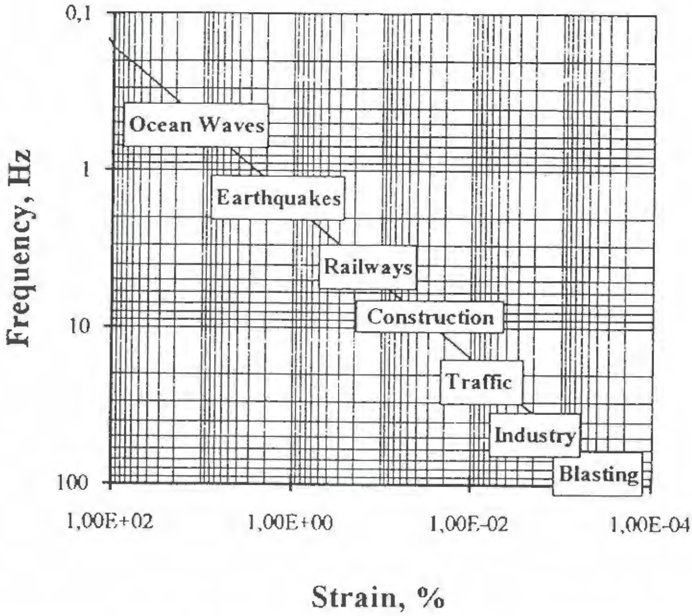

Figure 5.1. Typical range of vibration amplitudes and frequencies for different vibration sources.

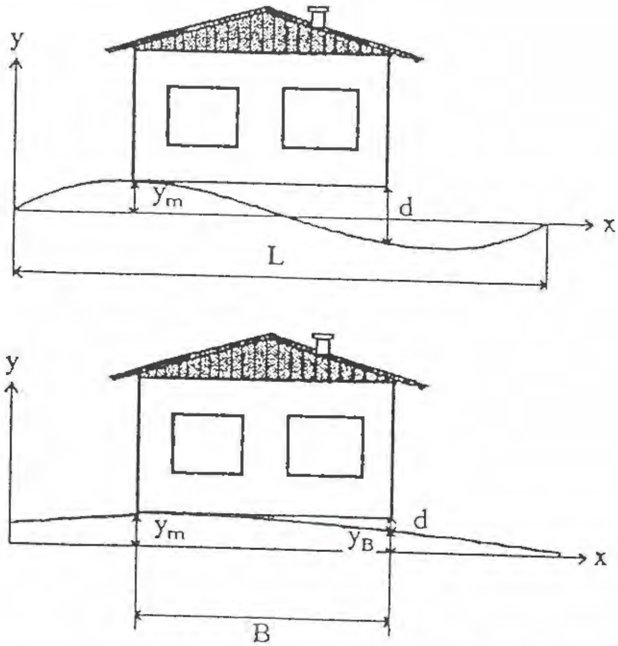

Figure 5.2. Influence of wave length on ground distortion below a building.

Reference:
Massarsch, K.R.(1993): *Man-made vibrations and solutions*, Third International Conference on Case Histiories in Geotechnical Engineering, St.Louis, June 1-5,1993. This paper is included in SGI Varia 437.

Secondary material

Mr R.J. Termaat, Rijkswaterstaat, Dienst Weg- Waterbouwkunde, Netherlands

Mr Termaat put the following questions on this subject:

Waste materials in embankments are used for two reasons:
- to use waste material
- to save natural resources.

The use of such materials are dependent on
- government legislation
- environmental requirements (very high). Requirements could be too strict.
- disposal costs versus construction costs.
- acceptance - it is impossible to force anyone to use waste materials. Hence, public relations projects are important. There are more or less political views.

The R&D activities must be focused on the following topics:

Reliable prediction of spreading
- 1-D and 2-D models for predicting pollution
- Risk analysis
- Evaluation models - the experience in the Netherlands is that models should be used in practical engineeriug.

Economic aspects
- Models for estimating costs

Creative design
- Functional requirements flexibility
- Engineering properties
- Sealing
- Drainage

Immobilization

- Methods of immobilizing the pollutants

Transfer of knowledge

- Introduce another way of thinking
- Manuals

Demonstration projects can be used to introduce new technology and for knowledge transfer.

The Dutch situation is that there is a comprehensive list of acceptable waste materials such as fly ash and consolidated dredging sludges (clay). It is possible to use these types of material, e.g in dams and dykes.

In the European soil mechanics societies, work is going on regarding "Geotechnics in landfill design and remedial works". This will result in technical recommendations.

"Road Structures - Research Programme"

Mr Aarno Valkeisenmäki, Finnish National Road Administration, Finland

In Finland there are environmental projects in the Road Structures Research Programme. Technical universities, consultants and industries will participate in the research work. From the environmental point of view, good quality material for current pavement structures will not be available in the future.

Mr Valkeisenmäki focused on some specific goals in the research programme. Improvement in the economy of road management and inreasing road serviceability as well as reducing environmental impacts are important areas. The use of waste material in road construction is a difficult and controversial issue.

The research programme is expected to produce new:

- Pavement and foundation structures
- Pavemeut and geotechnical design guidelines
- Quality control systems
- Working methods
- Environmental protection guidelines.

"Performance of geotechnical barriers to contaminated flow"

Mr Richard Driscoll, Building Research Establishment, Great Britain

It has been estimated that there are more than 100,000 contaminated sites in the U.K. Sources of contamination include old gas-workings, old steel manufacturing plants, fuel depots and waste deposits.

Increasing use is being made of slurry-trench techniques to construct vertical barriers to prevent contaminant fluid flow. The walls are generally constructed by excavating trenches under a bentonite-cement slurry to depths of up to 10-12 metres. Typical material specifications are:

- Bentonite 50 kg
- Cement 125 - 200 kg (Portland cement (30 %); ground granulated slag (70 %)).
- Water 1000 kg

Typical performance specifications are :

- Permeability < 10^{-9} m/s
- Strain at failure > 5 %
- Compressive strength : 100-350 kPa at 28 days
- Durability

Plastic membranes are increasingly being installed vertically into slurry trenches.

The BRE has a research programme to investigate the in-situ performance of these barriers. While extensive research has examined the laboratory behaviour of many different material mixes, in the presence of different chemicals, very little attempt has yet been made to study the integrity, permeability and durability of these barriers.

The research programme involves locating existing barriers, drilling, sampling and conducting in-situ permeability tests to supplement laboratory sample tests. Also, new barriers are being instrumented to assess long-term field behaviour.

"Protection of slopes against chemical transporting"

Mr Hans Rathmayer, Technical Research Center of Finland, Finland

The purpose of groundwater protection at road slopes is to prevent contamination of groundwater in the case of accidents, to prevent the penetration of contaminants into a groundwater reservoir for a period of 12 hours and to prevent contamination by road salt. There are some limitations such as

- depth of frost penetration from 1.6 to 3 metres
- the contaminated materials are unknown
- the season and weather conditions are unknown in advance
- the drainage conditions vary widely.

An inventory of existing slope protections in Finland shows that glacial till and dry-crust clay are used. The disadvantages are susceptibility to surface erosion and suffusion, frost susceptibility and shrinkage/cracking when drying out.

Mr Rathmayer gave some requirements for soil liners regarding the permeability, field and laboratory testing and the short-term testing.

Alternative solutions are well compacted soil liners, geomembranes and a protective layer, geomembranes, soil and geosynthetic clay liner. For each of these alternatives there are several advantages as well as disadvantages. A list of requirements and procedures for testing geosynthetic materials for approval as barriers in slope protection was presented.

Finally, Mr Rathmayer pointed out that the following measures for quality control should be taken at the constructiou site:

- Random control of delivery documents, including the corresponding certification of production QC-measures
- Visual inspection of all joints, continuity of inlay and width of the overlapping
- If necessary, control of the joint structure and joint performance in a box-loading test.

Chapter 6.
Mutual Research Needs

Following the lectures on the first day, working groups met to discuss the proposed topics and to evaluate research needs. The outcome was presented and discussed in a following session. The discussions focused on:

- Selection of main topics
- Identification of problem areas mutual infrastructure problems related to soil, rock and groundwater
- Research needs
  - focus on common needs
  - current research activities
- Potential co-operative research needs
  - co-operation between two or more countries
- Conclusions and preliminary report

The officials (chairman and secretary) of the groups were selected by the organizing committe:

Research area	Chairman	Secretary
Geotechnical design	JP Magnan	R Larsson
Foundation engineering	M Jamiolkowski	P Löfling
Environmental geotechnics	FBJ Barends	E Ekstrand
Control and quality assurance	R Driscoll	B Rydell

6.1 GROUP 1 - GEOTECHNICAL DESIGN

Chairman Professor Jean-Pierre Magnan
Secretary Mr Rolf Larsson

Participants: F Barends (NL), U Bergdahl (S), B Dehlbom (S), E Ekstrand (S), W Haegeman (B), J Hartlén (S), H Ingvarsson (S), K Karlsrud (N), S Liedberg (S), R Massarsch (S), B Paulsson (S), A Valkeisenmäki (SF).

6.1.1 Selection of most important R&D areas

The discussion ended up with three important R&D areas:

- application of Eurocode 7
- probabilistic design
- experimental data from field tests

6.1.2 Problem areas and research needs

The following conclusions were established:

1. One of the coming problems is the **application of Eurocode 7**, which will be of common interest in the future. Further discussions on the practical application of this text must go on as well as rules for implementation of Eurocode 7. Some sort of organization consisting of institutes and other organizations in the field of geotechnics should be formed for lobbying in order to achive an appropriate form.

   Activity areas must be identified and persons who already are involved in activities of this kind ought to be assembled. Perhaps a seminar like this should be arranged in the near future.

2. Another type of activity that could be organized is in the area of **probabilistic design**. Risk assessment and probabilistic design is an area where much research is directed towards the failure state. However, much more experience is also needed on the parameters used for the serviceability state. There is a great need for a critical assessment of what elements of probabilistic design concepts have the greatest potential for finding practical applications. A seminar where researchers and practising engineers come together may be a first step towards addressing this issue.

3. Sharing of **experimental data from field tests**. There are few such research programs. There is therefore a need, for example, to organize field tests, but this is time-consuming and difficult to organize.

   There are many administrative problems in organizing an international database for research projects for geotechnical engineering because it involves a lot of people. A solution could be to have the names of contact persons for various topics. It was agreed that people undertaking common research should meet more regularly, e.g. engineers developing the lime-column method and engineers evaluating spring constants for calculation programs for strutted excavations. It was also pointed out that there was a need for these meetings to include a suitable mix of people of different ages, experience, views and interests.

6.1.3 Proposed joint research activities

Mr Karlsrud will form a policy together with Prof Barends and Prof Magnan in the area of probabilistic design and they will consider arranging a special seminar on this issue.

6.2 GROUP 2 - FOUNDATION ENGINEERING

Chairman Professor Michele Jamiolkowski
Secretary Mr Per Löfling

Participants: R Driscoll (U.K.), L Eriksson (S), N Foged (DK), T E Frydenlund (N), G Holm (S), L Jendeby (S), L Pettersson (S), H Rathmayer (SF), B Rydell (S), R.J. Termaat (NL).

6.2.1 Selection of most important R&D areas

The discussion ended up with two important R&D areas:

- geophysical methods in ground property measurement
- deep mixed-in-place methods

Other areas which were discussed:

- settlements of embankments on soft clays
- settlements of piled foundations
- friction piles
- constructive models
- impervious barriers

6.2.2 Problem areas and research needs

The following research needs were identified, based on the two areas with priority as above:

1. Further development is needed for equipment and procedures as well as for interpretation and significance of the results obtained. Furthermore, their use in design must be developed in order to get these methods more used in practice. Finally there is a potential for using these methods for quality control.

2. Deep mixed-in-place methods
   There are several potential applications and there is a need for a range of

these applications in different soils to predict the properties of the improved soil. Preliminary design criteria based on laboratory tests must be developed as well as design philosophy including interaction between soil and columns but also the durability of the reinforcement. Finally, methods for quality control must be developed, e.g. by checking performance by field tests on columns.

6.2.3 Proposed joint research activities

To explore the possibilities of co-operation in R&D the following proposals were made:

1. One-day workshop on geophysical methods, involving testing equipment manufacturers, practical users and researchers. A preliminary programme was subsequently suggested by Professor M Jamiolkowski and Mr R Driscoll and sent to SGI.

2. On behalf of the representatives of the Scandinavian Road Administrations, SGI will explore the feasibility of joint research projects on deep mixed-in-place methods involving specialized European contractors, material producers and road authorities.

6.3 GROUP 3 - ENVIRONMENTAL GEOTECHNICS

Chairman Professor Frans Barends
Secretary Ms Eva Ekstrand

Participants: U Bergdahl (S), B Dehlbom (S), W Haegeman (B), J Hartlén (S), H Ingvarsson (S), K Karlsrud (N), R Larsson (S), S Liedberg (S), J-P Magnan (F), R Massarsch (S), B Paulsson (S), A Valkeisenmäki (SF).

6.3.1 Selection of most important R&D areas

The discussion resulted in the definition of four areas with highest priority:

- use of secondary materials/saving natural resources
- pollution control
- slope protection/landslides
- vibrations

Other areas of interest were:

- contaminated soil
- soil improvement/waste improvement
- groundwater

6.3.2 Problem areas and research needs

Use of secondary materials/saving natural resources

The main problems with secondary materials are the question of durability and the lack of compliance test of such materials. There is also a lack of knowledge of the geotechnical properties and performance of many potential materials.

Use of secondary materials means that the geotechnical discipline will be enlarged with help from chemists, physicists and other disciplines. The knowledge of testing geotechnical properties has to be improved when new parameters such as durability must be introduced. The geotechnical data for waste materials should be equated to those of natural soils. Each country must set its own national levels and decide on a set of test methods (durability tests for example).

Pollution control

Pollution control means preventing pollution, and the rectification of already contaminated sites. There is a need for methods for predicting what can happen. The main problems in this field are durability of protective barriers and identification of types of pollutants and the way they may spread. The questions are: What geological/geohydrological areas are sensitive to pollution? What can be protected and what are the protection methods? What techniques can be used for protecting groundwater resources etc.

An important question is how contaminated soil affects the surroundings and how to ensure isolation of polluting areas (to groundwater). Barriers, geotechnical or fabricated, are one way to prevent the spread of pollution in soil. The question is the durability of geomembranes.

Slope protection/landslides

Slope stability is an environmental problem and several questions were raised: How does one protect steep slopes, soil nailing structures, gabions, etc.? Can displacements in slopes be forecasted? What are the effects of vegetation etc. (on material properties, stability, etc.) There are methods to monitor creep movements - but what are acceptable levels. Alternatively what alarm levels are to be used?

Vibrations

Vibrations from traffic and construction work, for example, may cause disturbance in the surroundings. The main problem with vibrations is to decide acceptable levels. The acceptance level set is, however, often very low and to a large extent due to psychological reasons.

Another problem is the prediction of vibrations and finding solutions. How does one evaluate the risk of vibration and what methods can be used to eliminate vibrations? Different kinds of measures must be employed, such as assessment measures, investigating measures, etc. The constructing stage must be influenced and vibrations from pile driving, for example, be considered. Geological aspects must also be considered.

6.3.3 Proposed joint research activities

To explore the possibilities of co-operation the following R&D areas were identified:

1. Use of secondary materials

- classification - available testing methods, compilation of international data
- alleviate standards of use

2. Pollution control

- durability of isolation
- identification of pollution type and area type
- document present status - present knowledge

3. Slope protection/landslides

- durability - long-term behaviour
- monitoring - type, equipment
- vegetation - benefit

4. Vibrations

- levels of acceptance
- use in practical design

The group did not discuss how this R&D should be carried out or how to co-operate. There are activities going on in some topics, which initially ought to be made clear. The problems must be approached and the discussion must go on between the participating countries before more precise projects can be formed.

6.4 GROUP 4 - CONTROL AND QUALITY ASSURANCE

Chairman Mr Richard Driscoll
Secretary Mr Bengt Rydell

Participants: L Eriksson (S), N Foged (DK), T E Frydenlund (N), G Holm (S), M Jamiolkowski (I), L Jendeby (S), P Löfling (S), L Pettersson (S), H Rathmayer (SF), R.J. Termaat (NL).

6.4.1 Selection of discussion areas

Questions concerning control and quality assurance are in focus and of the same nature in all countries.

The discussion included the following three areas of quality aspects:
- the need for appropriate knowledge and education
- quality systems and quality management
- procurement of geotechnical services

6.4.2 Problem areas

Knowledge and education

A fundamental prerequisite is that the people involved in field investigations and in engineering works must be qualified for the activities of the project concerned. In some cases there is a large spectrum of geotechnical engineering in small companies, which makes it difficult to estimate the competence level of each employee.

There has been much debate in the UK about the many geotechnical problems resulting from inadequate site investigation. Decisions were made to recommend the use of suitably qualified and experienced personnel at all stages of the investigation and design processes.

Different types of certification activities are available but they are used with different emphasis in the different countries, normally administered by the national geotechnical societies. Special qualifications are required in Eurocode 7 where geotechnical problems are divided into three categories. There is also a need for education of purchasers of geotechnical services.

Quality systems and quality management

Quality systems are necessary to obtain the appropriate quality level. A quality system must include management quality, quality in procedures and in testing methods. In addition, these systems must comprise all types of geotechnical service such as field and laboratory investigations, computer programs and engineering work. Certification and accreditation is useful but is just the lowest level of quality assurance. Quality management must be based on continuous improvement.

Quality activities at the European level are the harmonization of testing standards, e.g. in the SPRINT-programme. The intention is to harmonize soil testing in the European context and Eurocode 7.

Different measures are taken in several countries. For example, in the U.K., the various bodies concerned with geotechnics produced the following initiatives to improve quality and control processes.

- The British Geotechnical Society (BGS) introduced a Directory of "geotechnical specialists", both companies and individuals (see Table 6.1 for basic qualifications required to join). This Directory has been widely distributed to all professionals involved with construction in the U.K.

- The Association of Geotechnical Specialists (AGS) - a group of consultants and contractors was formed who hold meetings and publish guidance. To qualify for membership, firms must have at least three persons listed in the BGS Directory.

- The British Drilling Association (BDA) - this body provides training for drillers and issues quality accreditation to drillers;

Table 6.1. BGS requirements for entry to the Directory.

■ Chartered engineer/geologist with minimum of 5 years relevant experience
or
■ Chartered engineer/geologist with a post-graduate qualification in geotechnics or soil mechanics <u>and</u> minimum of 3 years relevant experience
or
■ Minimum of 20 years experience as a geotechnical specialist

In addition, the National Measurement Accreditation Service (NAMAS) provides certification of quality procedures in laboratory testing and office practices. Public bodies, for example highway authorities, plan to make NAMAS accreditation mandatory for contractors.

Procurement of geotechnical services

The important aspect for the buyer is to obtain appropriate results, not the way the service is carried out. The delivering company must be responsible for its product according to the specifications. One problem for the purchaser is to verify the service produced. It is important to define the requirements very clearly in the tender documents. Another problem is the insufficient knowledge of buyers in the geotechnical field. There is a need for some geotechnical knowledge at the very beginning of all construction work - a geotechnical adviser.

The Institution of Civil Engineers (ICE) is producing guidance on improved procurement, planning and quality in site investigation. The reports place great emphasis on the use of 'geotechnical advisors' at all stages in a project; such 'advisors' may be found in the Directory, but the reports develop their own set of qualifications, based on training, experience and study. The reports emphasize the importance of selecting a short-list of companies, based on quality.

6.4.3 Proposed joint development activities

The common opinion of the participants was that they shared the same problem of insufficient geotechnical information in different stages of the building process. The geotechnical investigations and design, control etc. are handled in different way in different countries. This will give different experiences. Maybe in a possible forthcoming seminar it would be interesting to discuss how these geotechnical problems are handled.

There are a lot of documents for quality assurance activities in each country. Some relevant national reports should be circulated between the participating countries.

6.5 SUMMARY OF R&D AREAS AND ACTIVITIES FOR POTENTIAL FUTURE CO-OPERATION

The results of the group discussions were presented in a plenary session. The following conclusions were made on mutual R&D areas and activities for potential future co-operation.

Application of Eurocode

It should be possible to form a group to work on the practical application of Eurocode 7 in order to achieve an appropriate form. Next step will be taken by Prof Magnan.

Probabilistic design

There is a need to share experience with others but also a need for research. A policy will be formed by Mr Karlsrud together with Prof Barends and Prof Magnan. (Such a proposal has been forwarded during discussions after the seminar).

Experimental data from test fields

It is difficult and very expensive to establish an interntional database for data from test fields. One question is how to have it updated. The meeting decided that "person-to-person" information exchange is the most appropriate.

Geophysical methods

A one-day workshop on the geophysical methods should be arranged. A programme was subsequently presented by Prof Jamiolkowski and Mr Driscoll. It was suggested that SGI should organize the workshop.

Deep mixed-in-place methods

Identify the feasibility of a joint research project, shared by many participants. SGI will initiate co-operation with the Scandinavian National Road Administrations.

Use of secondary materials

Knowledge is at an early phase but there is political pressure. The next step will be the WASCON conference in Maastricht in 1994. There is a need for more test methods, e.g. durability testing.

Pollution control and prevention

A high priority area including many complex questions. NORDTEST, run by the Nordic Council of Ministers, is a group working with test procedures. No further activities just now from the participants of the seminar.

Slope protection/landslides
In the new environmental programme in the EU research programme, the area of landslides is topical. SGI will analyse the research programme and if there are any possibilities, the SGI will contact the conference members.

Vibrations
Very important area but no decision was made on future activities just now.

Quality assurance
Information and relevant national reports should be sent to the SGI for distribution. Methods for quality management and application in the geotechnical field could be developed and shared between the participants.

Chapter 7.

Dissemination and Use of Geotechnical Knowledge

Chairman: Professor Hans Ingvarsson, Swedish National Road Administration, Sweden

An important part of research work is to implement the research results into practice. For that reason, a special session was held concerning the use of geotechnical knowledge and technology transfer.

7.1 INTRODUCTION

As an introduction, Prof Ingvarsson reported on the work in progress on the road design codes which are built up by:

- operation code and maintenance code
- bridge code
- tunnel code.

The SNRA has as a main task of production of these codes and is involved in the Western European Road Directors as well.

Two sub-committees are working on the implementation of the Construction Products Directive and the Procurement Directive of Europe. Work is also progressing on Swedish National Application Documents (NAD) connected to Eurocodes 2 and 7.

After the introductory presentation, the session was divided into three parts:

1. *Prepared contributions from Sweden*
2. *General discussion*
3. *Conclusions*

7.2 DISSEMINATION OF R&D RESULTS AND TECHNICAL TRANSFER IN SWEDEN

Mr Bengt Rydell, Swedish Geotechnical Institute, Sweden

In his presentation, Mr Rydell described procedures for using existing and new knowledge in a Swedish perspective. The presentation included three parts, the SGI strategy, other Swedish organizations and international outlook.

The SGI strategy

The foundation of the SGI activities consists of three main programme:

- R&D
- information
- consultancy

The interaction between these programmes is illustrated by *Figure 7.1.*

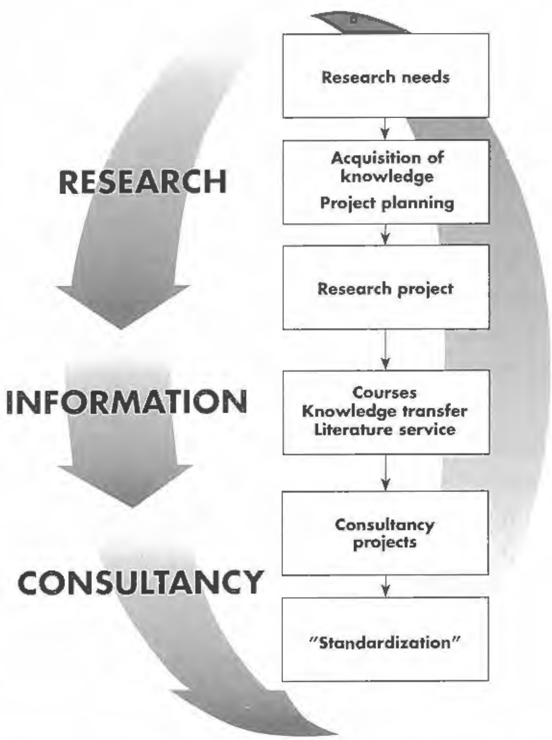

Figure 7.1. The SGI loop - from research to practical application.

The task for the SGI is to carry out R&D and bring it to practical application. Here information activities are a necessity. At the SGI, information activities amount to more than 15 % of the annual turnover, corresponding to about 75-80 % of the total geotechnical information activities in Sweden.

The Institute's role on the market is to provide a link between university research and its practical application and evaluation in planning and construction. A close interaction between the three areas above results in quickly used practical applications.

As Sweden's geotechnical information centre, the SGI has an active role in communicating knowledge to various groups of the community. The task is to present the information in the best suitable form, using various types of activity. These activities are often performed in co-operation with parties concerned, such as specialist organizations and research bodies.

The SGI loop describes different ways to communicate and transfer knowledge
- the written word: Literature
- the spoken word: Education
- the action: Codes and Practice

Literature Service
The SGI literature service provides library services, database retrivals and evaluation of literature, and offers an awareness service for foreign publications, as well as literature exchange with some 300 foreign research institutions. The SGI operates a unique computerized geotechnical database, the SGILINE. The literature service is also an asset for long-term basic research at the Institute and universities in Sweden and abroad.

The Institute communicates research results and practical knowledge to various groups through publications such as reports, recommendations, guidelines, manuals and technical basis for standards. Research results are also reported at Swedish and international conferences.

Education
The SGI arranges courses on a variety of geotechnical themes for different groups in the building sector. Presentations are mainly made by the Institute's own personnel, although courses are often arranged jointly with other authorities, institutes of technology and various specialist organizations. Training and courses are arranged for consultants, contractors and customers in government

and private organizations in subjects as field investigations, calculation methods and environmental applications.

In addition, the SGI participates in education at the universities of technology through an assistant professor at Chalmers, and by lecturing. The SGI also co-operates in order to facilitate postgraduate studies at the SGI as a part of the studies as well as students diploma work related to the research at the SGI.

Codes and Practice
On the Swedish market, the Institute acts as an independent body with wide-ranging interaction involving Government authorities, universities and private companies. The SGI produces basic documentation for drawing up recommendations, rules and standards, e.g. for the Swedish building code together with the National Board of Housing, Building and Planning and National Application Documents corresponding to Eurocodes.

By consultancy operations, research results can be implemented in practice and feedback communicated to research and information activities.

An example of good interplay with different categories is the EMBANKCO settlement calculation program together with the SNRA and based on the CESAR-LCPC program. Another example is the development of stabilization with lime/cement columns done together with industry and the SNRA.

Other Swedish organizations
Besides SGI, there are some other authorities and organizations dealing with information activities in the geotechnical field. Some of them are presented briefly below:

• *The Swedish Council for Building Research (BFR)* is active in several areas in the building sector, e.g.by financing demonstration plants and testing new techniques at full scale. Two examples are a test field for heat storage at high temperature in soft clay and vibration isolation using membranes in soil.

• *The Swedish Geotechnical Society (SGF)* is the professional body representing Swedish geotechnical engineers and produces recommended standards in the geotechnical area and organizes conferences and lectures on different topics.

• *The Swedish Pile Commission* is built up by members from authorities, contractors, manufacturers and consulting companies. The Commission is under the auspices of the Royal Swedish Academy of Engineering Sciences (IVA). This gives a unique form of co-operation. The Commission activities are R&D and technology transfer of pile foundations.

• *The Swedish Commission on Slope Stability* is under the auspices of IVA as well. This Commission initiates and co-ordinate R&D-activities on slope stability and precautionary methods. The Commission also produces reports and works with information activities to municipal authorities and geotechnicians.

• *The Development Fund of the Swedish Construction Industry (SBUF)* finances studies on practical applications in close co-operation with researchers and contractors.

International outlook - from the Swedish point of view

Corresponding to R&D, joint projects should be more deeply established concerning information activities. This would enable better use because of of limited financial resources.

In the ongoing EU programmes there are some activities that could be used for the transfer of knowledge. In the COMETT and Eurobuild networks, information could be exchanged, e.g. exchange of researchers and student exchange for short or long periods.

The SGI is establishing a network in Sweden for joint European activities. This network could be co-ordinated with a corresponding European network, based on the organizations represented at this seminar and others.

In the following **discussion** Mr *H Rathmayer* asked whether there was any conflict between research and consultaucy at the SGI so that research results would be kept within the organization. Mr *B Rydell* replied that there is normally no conflict. When SGI receives research funds, the results always are published. However, there is also research funded by private clients and in these cases the results are the clients property.

Mr *K Karlsrud* noted that there is a practical problem in some cases when an organisatiou can be accused of keeping results. At the NGI there is very little funding for getting out information. Mr *T Frydenlund* mentioned that in research contracts with the NGI, for example, the NPRA compiles the information and distributes it.

7.3 USE OF GEOTECHNICAL KNOWLEDGE

Mr Leif Pettersson, Swedish National Road Administration, Sweden

The presentation was based on answers on a questionnaire sent to the participants before the seminar. The answers show many different ways of distributing knowledge.

New geotechnical knowledge emanates mainly from universities of technology and research institutes. It may take the form of theses or results of commissions from companies and authorities.

From the answers on the questionnaire it appears that the ways of distributing geotechnical knowledge are almost the same in all countries. One can distinguish four different ways of distributing new geotechnical knowledge.

1. Participation in different kinds of conferences and committees.
2. Reports, publications, manuals and theses.
3. Codes of practice, design guides, regulations and standard specifications.
4. Different courses (education).

Authorities and research institutes concentrate on regulations, codes of practice and standard specifications while technical universities concentrate on theses.

The risk is that new knowledge from research institutes and universities will not reach the users. The tender procedure as a way to transfer knowledge is underestimated. The cost for implementation of new knowledge in practical use is often not included in the R&D-project. Because of that, the results will stay inside the universities.

Based on the answers, Mr Pettersson stated that the exchange of knowledge between universities and research institutes is strong but the exchange of knowledge between the "academic world" and practice is weak. A company's interest in investing in R & D is directly dependent on how fast the results can be used in practice. The conclusion must be that transfer of knowledge needs to be improved.

As a basis for the discussion Mr Pettersson rasied the following questions:

Is it possible to
- reduce the time
- reduce the costs
- reduce the risk of error

from R&D results to practice?

In the **discussion** Mr *R Driscoll* pointed out that communication between geo-specialists and other construction professionals is a problem everywhere. Some construction people believe they do not need geo-specialists. The UK Institution of Civil Engineers has started a new journal, "Geotechnical Engineering" with an objective of education construction professionals about the complexities of geotechnics and the advantages of employing geo-specialists.

Mr *U Bergdahl* mentioned a Swedish example of a way of getting research efforts to the public. The research results of the Pile Commission come into production very quickly. The main thing is that there is a group of people interested in the saine subject.

Mr *G Holm* added that both researchers, practical engineers, consultants and contractors are members of the Pile Commisson and are eager to put research results into practice. When a report is ready, a seminar is arranged.

7.4 GENERAL DISCUSSION AND CONCLUSIONS

The chairman, Prof Ingvarsson, stressed that there is a need for transfer of know-how between different categories of organizaions and people, such as
- technical universities
- research institutes
- consulting engineers
- contractors
- clients
- authorities.

The chairman then put two questions:
1. Who or what speeds up the know-how transfer in your country?
2. Opposite - who/what is blocking the know-how transfer?

The answers of the representatives of the different countries showed that there were several similar conditions in the countries.

The most efficient activities to knowledge transfer are made by government authorities and R&D organizations and to some extent the industry. The geotechnical societies and different technical committees are also important for dissemination of knowledge.

The best ways of this transfer, the channels, are technical standards, courses/education and experience from failures.

A main obstacle for knowledge transfer is lack of money or inappropriate use of money. Furthermore, R&D results in some cases are kept within the industry and the results are used for competetive advantage. Another problem is that it takes time to make reports and it is costly to make presentations. It is a challenge to get funding for this type of important work.

This leads to the following conclusions:

- Authorities must
  - promote and sometimes force the industry to fund money for knowledge transfer or do it themselves. It is very important to establish "Centres of Excellence" in the geotechnical field and in multi-disciplinary fields of activity.
  - understand the "R&D-language", take greater responsibility concerning the implementation of R&D results and bring them into practice.

- R&D people have to put know-how into the system and learn how to bring the research results to the market for commercial use.

Chapter 8.

Closing Remarks

Chairman: Dr Jan Hartlén, Swedish Geotechnical Institute, Sweden

The chairman began by expressing his satisfaction with the way this seminar had turned out. He thought that it was the best way to transfer knowledge of current research activies.

The benefit of geotechnical engineering to the society

From the group discussions, it was pointed out that the assembled group did not represent the whole geotechnical profession, but organizations with a special role in it. The geotechnical institutes are supposed to give required geotechnical service to their countries in terms of, for example, validation of design and calculation methods, and to pass information on geotechnical developmnent to the profession. In all countries there generally is a broad gap between research, especially at the universities, and practice.

There is also a great need for general information on the benefit of geotechnical engineering to society. Activities at the geotechnical institutes should be focused on public needs in terms of safe and economic designs rather than promoting personal interests and the individual institutions. Possible co-operation on a broader basis should be seen in this light. Most research co-operation is on a small personal basis for which formal agreements are not necessary. Co-operation on a larger, multinational scale, towards common goals, is more a politicial question.

It was also pointed out that co-operation is difficult and requires the institutions involved to be prepared. This means finding common ground and listening rather than showing off personal ideas. It was unaminously decided to explore the possibilities of forming an association or network for the national geotechnical institutes with the aim of promoting co-operation and forming a geotechnical programme for geotechnical research and development within Europe.

Future co-operation

The chairman asked if a seminar like this should be arranged about 1½ years from now? Should it be oriented towards specific subjects or be more general, say a repeat of this seminar?

In the discussion it was pointed out that it is of value to come to a forum for discussing research. The research activities are different in different countries because of, for example, the climate. An idea could be to focus on highlighted projects. In the EU, most geotechnical research is funded by governments. There is a lot of competition for such funds.

The chairman also raised the question of forms of future co-operation, in this network and in the EU-perspective. "When do you think that research will have reached the level at which it cannot go further?"

The participants mentioned that in the EU, the geotechnical market has no voice. There is a need for a strong voice on this issues because there is no industry that helps in the lobbying.

Limitated funds available to travel abroad prevents people from getting to know one another better. One way could be joint activities in the EU research programme. However, bureaucracy is growing; up to 25 % of all money is often used before the research projects start. All administrative problems associated with research should be solved before starting the research. We probably cannot get more money through the EU so with less money or the same amount, we must work more efficiently. An exception may be the environmental field, which is growing.

The participants focused on the possibility of two or three countries working on the same research project as a very good solution. A good network would be positive. The possibility of applying for grants from the EU for arranging meetings like this seminar could be used. Soil mechanics would be a big enough issue.

Acknowledgement

Finally, the chairman once again expressed the acknowledgement of the SGI and SNRA to the participants and closed the meeting with the words: "We shall meet again."

Appendix

APPENDIX 1: SEMINAR PROGRAMME

Tuesday, November 16, 1993

09.00	**Welcome addresses** **Presentation of participants**	Mr. Bengt Holmström Dr. Jan Hartlén
09.30	**Plenary session 1** **Geotechnical design**	Chairman Mr. Kjell Karlsrud
12.30	*Lunch*	
13.30	**Plenary session 2** **Foundation engineering**	Chairman Prof. Niels Foged
16.00	**Plenary session 3** **Environmental geotechnics**	Chairman Dr. Jan Hartlén
18.00	**Introduction to group discussions**	
19.00	*Dinner*	
20.00	**The Leaning Tower of Pisa** **Lecture**	Prof. Michele Jamiolkowski
	Informal discussions	

Wednesday, November 17, 1993

08.30	**Group discussions** Parallel sessions - Geotechnical Design - Foundation engineering - Environmental geotechnics - Control and quality assurance	 Chairman Prof. Jean-Pierre Magnan Prof. Michele Jamiolkowski Prof. F.B.J. Barends Mr. Richard Driscoll
12.30	*Lunch*	
13.30	**Plenary session 4** **Presentation of major results from the group discussions**	Chairman Dr. Jan Hartlén

15.30	**Plenary session 5** **Use of geotechnical knowledge** - Dissemination of R&D results - Technology transfer	Chairman Prof. Hans Ingvarsson
16.30	**Plenary session 6** **Forms of co-operation** - Joint activities - European network	Chairman Dr. Jan Hartlén
17.30	**Summing up** Closing remarks	
19.00	*Dinner*	
	Informal discussions	

Thursday, November 18, 1993

09.00	**Overview of the development plan for the communications in the Stockholm Region**	Mr. Lars Bjerin, SNRA, Stockholm
09.50	**Departure to Stockholm and visit to road junction at Haga Norra**	
11.30	**Information on the traffic communication solution for the Stockholm Region, with special reference to the road ring**	Mr. Per-Olof Sahlström, SNRA, Stockholm
13.00	*Lunch*	
14.00	**End of seminar**	

APPENDIX 2: LIST OF PARTICIPANTS

Photo:Ulf Lodin

Belgium
Dr. W. Haegmen, *Ghent University*

Denmark
Prof. Niels Foged, *Danish Geotechnical Institute*

Finland
Mr. Hans Rathmayer, *Technical Research Centre of Finland*
Mr. Aarno Valkeisenmäki, *Finnish National Road Administration*

France
Prof. Jean-Pierre Magnan, *Laboratorie Central des Ponts et Chaussées*

Italy
Prof. Michele Jamiolkowski, *Politecnico di Torino*

The Netherlands
Prof. F.B.J. Barends, *Delft Geotechnics*
Mr. R. J. Termaat, *Rijkswaterstaat, Dienst Weg- Waterbouwkunde*

Norway
Mr. Tor Erik Frydenlund, *Norwegian Public Road Administration*
Mr. Kjell Karlsrud, *Norwegian Geotechnical Institute*

United Kingdom
Mr. Richard Driscoll, *Building Research Establishment*

Sweden
Mr. Ulf Bergdahl, *Swedish Geotechnical Institute*
Mr. Björn Dehlbom, *Swedish National Rail Administration*
Mr. Leif Eriksson, *Swedish Geotechnical Institute*
Mr. Göran Holm, *Swedish Geotechnical Institute*
Mr. Bengt Holmström, *Swedish National Road Administration*
Prof. Hans Ingvarsson, *Swedish National Road Administration*
Dr. Leif Jendeby, *Chalmers University od Technology*
Mr. Rolf Larsson, *Swedish Geotechnical Institute*
Dr. Sven Liedberg, *Chalmers University of Technology*
Mr. Per Löfling, *Swedish National Road Administration*
Prof. Rainer Massarsch, *Royal Institute of Technolocy*
Mr. Björn Paulsson, *Swedish National Rail Administration*
Mr. Claes Unge, *Ministry of Transport and Communications*

Organizing Committee

Dr. Jan Hartlén, Chairman	Director General, Swedish Geotechnical Institute
Mr. Bengt Rydell, Secretary	Head of Information and Marketing Department, Swedish Geotechnical Institute
Ms. Eva Ekstrand	Geotechnical Section, Swedish National Road Administration
Mr. Leif Pettersson	Head of Geotechnical Section, Swedish National Road Administration

APPENDIX 3: SGI VARIA 437

Seminar on Soil Mechanics on R&D for Roads and Bridges. National Reports, Literature and Technical Papers

CONTENTS

STATENS GEOTEKNISKA INSTITUT
SWEDISH GEOTECHNICAL INSTITUTE

Serien "Rapport" ersätter våra tidigare serier: "Proceedings" (27 nr), "Särtryck och Preliminära rapporter" (60 nr) samt "Meddelanden" (10 nr).

The series "Report" supersides the previous series: "Proceedings" (27 Nos), "Reprints and Preliminary Reports" (60 Nos) and "Meddelanden" (10 Nos).

RAPPORT/REPORT

No		År/Year
1.	**Grundvattensänkning till följd av tunnelsprängning** P. Ahlberg & T. Lundgren	1977
2.	**Påhängskrafter på långa betongpålar** L. Bjerin	1977
3.	**Methods for reducing undrained shear strength of soft clay** K.V. Helenelund	1977
4.	**Basic behaviour of Scandinavian soft clays** R. Larsson	1977
5.	**Snabba ödometerförsök** R. Karlsson & L. Viberg	1978
6.	**Skredriskbedömningar med hjälp av elektromagnetisk fältstyrkemätning - provning av ny metod.** J. Inganäs	1978
7.	**Förebyggande av sättningar i ledningsgravar -en förstudie** U. Bergdahl, R. Fogelström, K.-G. Larsson & P. Liljekvist	1979
8.	**Grundläggningskostnadernas fördelning** B. Carlsson	1979
9.	**Horisontalarmerade fyllningar på lös jord** J. Belfrage	1981

RAPPORT/REPORT No		År/Year
10.	**Tuveskredet 1977-11-30. Inlägg om skredets orsaker**	1981
11a.	**Tuveskredet - geoteknik**	1984
11b.	**Tuveskredet - geologi**	1981
11c.	**Tuveskredet - hydrogeologi**	1981
12.	**Drained behaviour of Swedish clays** R. Larsson	1981
13.	**Long term consolidation beneath the test fillsat Väsby, Sweden** Y.C.E Chang	1981
14.	**Bentonittätning mot lakvatten** T. Lundgren, L. Karlqvist & U. Qvarfort	1982
15.	**Kartering och klassificering av lerområdens stabilitetsförutsättningar** L. Viberg	1982
16.	**Geotekniska fältundersökningar** Metoder - Erfarenheter - FoU-behov. E. Ottosson (red.)	1982
17.	**Symposium on Slopes on Soft Clays**	1983
18.	**The Landslide at Tuve November 30 1977** R. Larsson & M. Jansson	1982
19.	**Släntstabilitetsberäkningar i lera** Skall man använda totalspänningsanalys, effektivspänningsanalys eller kombinerad analys? R. Larsson	1983

RAPPORT/REPORT No		År/Year
20.	**Portrycksvariationer i leror i Göteborgsregionen** J. Berntson	1983
21.	**Tekniska egenskaper hos restprodukter från kolförbränning - en laboratoriestudie** B. Möller, G. Nilson	1983
22.	**Bestämning av jordegenskaper med sondering - en litteraturstudie** U. Bergdahl & U. Eriksson	1983
23.	**Geobildtolkning av grova moräner** L. Viberg	1984
24.	**Radon i jord** - Exhalation - vattenkvot - Årstidsvariationer - Permeabilitet A. Lindmark & B. Rosén	1984
25.	**Geoteknisk terrängklassificering för fysisk planering** L. Viberg	1984
26.	**Large diameter bored piles in non-cohesive soils** Determination of the bearing capacity and settlement from results of static penetration tests (CPT) and standard penetration test (SPT). K. Gwizdala	1984
27.	**Bestämning av organisk halt, karbonathalt och sulfidhalt i jord** R. Larsson, G. Nilson & J. Rogbeck	1985
27E.	**Determination of organic content, carbonate content and sulphur content in soil** R. Larsson, G. Nilson & J. Rogbeck	1987

RAPPORT/REPORT No		**År/Year**
28.	**Deponering av avfall från kol- och torveldning** T. Lundgren & P. Elander	1986
28E.	**Environmental control in disposal and utilization of combustion residues** T. Lundgren & P. Elander	1987
29.	**Consolidation of soft soils** R. Larsson	1986
30.	**Kalkpelare med gips som tillsatsmedel** G. Holm, R. Tränk & A. Ekström	1987
	Användning av kalk-flygaska vid djupstabilisering av jord G. Holm & H. Åhnberg	
	Om inverkan av härdningstemperaturen på skjuvhållfastheten hos kalk- och cementstabiliserad jord H. Åhnberg & G. Holm	
31.	**Kalkpelarmetoden** Resultat av 10 års forskning och praktisk användning samt framtida utveckling. H. Åhnberg & G. Holm	1986
32.	**Two Stage-Constructed Embankments on Organic Soils** 1988 ☐ Field and laboratory investigations ☐ Instrumentation ☐ Prediction and observation of behaviour W. Wolski, R. Larsson et al.	
33.	**Dynamic and Static Behaviour of Driven Piles** (Doctoral thesis) Nguyen Truong Tien	1987
34.	**Kalksten som fyllningsmaterial** J. Hartlén & B. Åkesson	1988

RAPPORT/REPORT

No		År/Year
35.	**Thermal Properties of Soils and Rocks** (Doctoral thesis) J. Sundberg	1988
36.	**Full-Scale Failure Test on a Stage-Constructed Test Fill on Organic Soil** W. Wolski, R. Larsson et al.	1989
37.	**Pore Pressure Measurement - Reliability of Different Systems** M. Tremblay	1989
38.	**Behaviour of Organic Clay and Gyttja** R. Larsson	1990
39.	**Gruvavfall i Dalälvens avrinningsområde - Metallutsläpp och åtgärdsmöjligheter** Rapport till Dalälvsdelegationen T. Lundgren & J. Hartlén	1990
40.	**Shear Moduli in Scandinavian Clays** - Measurement of initial shear modulus with seismic cones - Empirical correlations for the initial shear modulus in clay R. Larsson & M. Mulabdic´	1991
41.	**Övervakningssystem - Släntbeteende - Skredinitiering Resultat från ett fullskaleförsök i Norrköping** B. Möller & H. Åhnberg	1992
42.	**Piezocone Tests in Clay** R. Larsson & M. Mulabdic´	1991
43.	**Footings with Settlement-Reducing Piles in Non-Cohesive Soil** Phung Duc Long	1993

RAPPORT/REPORT No		År/Year
44.	**Agnesbergsskredet** R. Larsson, E. Ottosson & G. Sällfors	1994
45.	**Agnesbergsskredet - Skredförebyggande åtgärder** H. Sandebring & E. Ottosson	1994

The Swedish Geotechnical Institute is a government agency dealing with geotechnical research, information and consultancy.

The purpose of the Institute is to achieve better techniques, safety and economy by the correct application of geotechnical knowledge in the building process.

Research

Development of techniques for soil improvement and foundation engineering. Environmental and energy geotechnics. Design and development of field and laboratory equipment.

Information

Research reports, brochures, courses. Running the Swedish central geotechnical library with more than 85.000 documents. Computerized retrieval system.

Consultancy

Design, advice and recommendations, including site investigations, field and laboratory measurements. Technical expert in the event of disputes.

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