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J.S. Steenfelt

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Soil Mechanics Paper No 15



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The papers are numbered ISSN 1398-6465 R<two digit year code><two digit consecutive number>. For internal purposes the papers are, further, submitted with coloured covers in the following series:

Series	Colour
Laboratory testing papers	sand
Field testing papers	grey
Manuals & guides	red
Soil Mechanics papers	blue
Foundation Engineering papers	green
Engineering Geology papers	yellow
Environmental Engineering papers	brown

In general the AGEP papers are submitted to journals, conferences or scientific meetings and hence, whenever possible, reference should be given to the final publication (journal, proceeding etc.) and not to the AGEPPaper.

National R&D Report: Denmark

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1. National R&D structure

The visible R&D activities within Soil Mechanics and Foundation Engineering are in Denmark principally carried out by:

- Aalborg University, Civil Engineering Department, Aalborg (4.5 M DKK)
- Danish Geotechnical Institute, Lyngby (4 M DKK)
- Technical University of Denmark, Civil Engineering Department, Lyngby (1.5 M DKK)
- Major consulting companies (2 M DKK)

where the number in parenthesis is the estimated economic input at cost value.

However, using the Danish Geotechnical Society as a vehicle for cooperation and dissemination of information and knowledge, relatively close contact and cooperation between the above institutions and the app. 300 members of the society is facilitated. The publications by the members (for 1994-1996) are listed in the Society's bi-annual report.

Recently this cooperation manifested itself through the organisation of the XI ECSMF in Copenhagen 1995, where the R&D spin-off from some of the recent very large infrastructure projects in Denmark were exposed in a special volume dedicated to the Storebælt and Øresund Link projects.

The R&D activities are financed by various channels where the distribution (indicated in parentheses) is an estimated average figure which covers major differences in-between institutions and companies. Note, that salaries to personnel constitute a major part of the self financing.

- Self-financing (45%)
- Support from the Danish Technical Research Council (20 %)
- EU-research programmes (20%)
- Private foundations (5%)
- Joint industry programmes (10 %)

The R&D activities are targeted to meet the requirements of national and international research strategies and the interests of the individual researchers.

Due to confidentiality restrictions a number of R&D projects related to the oil industry are carried out but not available for this compilation. The same applies to other industry based internal R&D (f.inst. development of IT tools for companies, development of new drilling tools).

2. Ongoing R&D projects

To exemplify the R&D activities some of the characteristic projects are listed below. Projects with a budget below 0.5 M Danish Kroner (DKK) have not been considered (1 DKK = 0.135 ECU):

Project name	<i>Dynamic response of coarse granular materials to wave loading</i>
Target	The objective is to provide the geotechnical input to develop a rational design method for concrete superstructures on rubble mound breakwaters and monolithic caisson structures on rubble foundations.
Approach	Theoretical studies and experimental determination of strength and deformation characteristics of coarse materials basically from large scale triaxial testing.
Partners	The project is related to EU project Marine Science and Technology, MAST II,

- with 14 European partners (Aalborg University, Norwegian Geotechnical Institute, Delft Geotechnics..)
- Budget 0.864 M DKK
- Project name *True Triaxial Apparatus, Mark II*
- Target Renovation of the existing Aalborg University true triaxial set-up with completely new electronic equipment for data acquisition and control and improvement of mechanical system. Through the renovation a state-of-the-art test set-up for material modelling is maintained.
- Budget 0.75 M DKK.
- Project name *A design tool for geotextile reinforced earth structures. An EU TRM programme (Training and Mobility of Researchers)*
- Target Improve modelling of the soil-geotextile interface in order to provide a more rigorous tool for the design of reinforced structures.
- Approach Analytical/numerical evaluation supported by laboratory and field tests to study the interaction.
- Partners Aalborg University and Danish companies.
- Budget 1 M DKK
- Project name *Behaviour of structures subjected to dynamic ground motion*
- Target Theoretical and experimental studies of the generation and propagation of shear, compression and surface waves in layered soils.
- Approach In situ measurements of train induced wave propagation in soils combined with experimental resonant column and dynamic triaxial tests to establish a database of dynamic properties for Danish soils. Data to be analysed by FEM modelling and simple energy dissipation theories.
- Partners Aalborg University (Danish Research Council project) and DSB but linked to LIT-ASEIS project with Århus University and several German Universities.
- Budget 1.7 M DKK
- Project name *COMBIRIG*
- Target To develop a lightweight combined CPT and vibrocore rig for operation at water depths up to 1000 m.
- Approach Development of rig based on a combination of technologies from existing heavy weight SCOPE CPT rig and development of new vibrocore unit.
- Partners Danish Geotechnical Institute
- Budget 4.7 M DKK
- Project name *KSP (Kinematically and Statically Plausible) programme for sheet wall design*
- Target Development of a commercially available Windows based sheet pile wall design programme based on kinematically and statically plausible rupture figures.
- Approach Development of EDP programme by Danish Geotechnical Institute and implementation by an industry financed PhD study (Technical University of Denmark) and supported by a text book financed through the TUR programme and the COWI foundation.
- Partners Danish Geotechnical Institute
- Budget 6 M DKK

Project name	<i>Joint Chalk Research phase IV</i>
Target	Development of laboratory methods for studying the influence of water flooding for oil depletion of chalk reservoirs and numerical reservoir simulation.
Partners	Danish Geotechnical Institute as lead partner in a consortium of Danish And Norwegian partners.
Budget	5.4 M NOK.
Project	<i>Preloading of embankments - an environmentally feasible solution for soft ground</i>
Target	Development of a numerical tool for optimisation of preloading and loading time based on laboratory determined deformation parameters and full scale monitoring of on-going construction of motorway embankments in Denmark.
Partners	Aalborg University and Carl Bro.
Budget	0.5 M DKK

3. Planned R&D activities

No real realistic long-term planning of R&D activities exists apart from the ubiquitous Strategic plans required by universities, companies and government alike. It is hoped that the on-going much needed expansion at the Technical University of Denmark will boost the R&D activities in the Copenhagen region by offering the Danish Geotechnical Institute competition and cooperation at the same time. The current and planned R&D activities by the three main participants, Aalborg University, Danish Geotechnical Institute and the Technical University of Denmark are supplementing rather than overlapping each other. This also means that a wider spectrum in terms of education and R&D themes will be available to the public, reflecting also the status of the Danish Geotechnical Society as an umbrella-society for activities in soil mechanics, engineering geology and rock mechanics.

The findings from the recent and on-going major infrastructure projects, the Storebælt, Øresund and Fehmarn Belt link projects and the Copenhagen mini-metro serve as inspiration for the R&D programmes as the projects have revealed several shortcomings in our basic understanding and handling of soil characterization, dynamic load-response interaction and soil modelling.

Based on the on-going R&D and the resources allocated to geotechnical engineering the following activities are foreseen.

- Continued R&D for the oil industry related to rock mechanical laboratory methods for 3D-stress state testing of claystone/shale, chalk and friable sandstone including effects of water and gas injection.
- 3D-modelling of stress-strain states in oil reservoirs and well bores.
- Salt creep testing and modelling of gas storage caverns in salt domes.
- R&D related to bentonite refinement and utilisation based on Danish Tertiary clay deposits based on a major, commercially viable bentonite deposit. This will interact with studies of Tertiary clays (swelling clays) in general which are problem soils in Denmark and will be decisive for the foundation of the Fehmarn Belt link project.
- Within the framework of existing R&D programmes an intensified study of soil dynamics problems, in particular degradation due to pore pressure build-up, will take place. The aim is a better understanding of soil behaviour based on establishment of soil parameter data bases and large scale experiments for creation, calibration and verification of viable constitutive models. Stochastic and probabilistic modelling will play a very important role in this development.

The results will form the basis for a better assessment and design involving new foundation concepts f.inst related to light-weight offshore platforms or offshore windmills.

- General, fundamental studies of selected soil types (sand, gyttja, clay till, Tertiary clay) in the laboratory using oedometer, triaxial and true triaxial testing for development of robust material models for implementation in FEM programmes.
- Through cooperation with neighbouring disciplines environmental geotechnics will be paid more attention, particularly related to in situ remediation of polluted ground and the influence of pollutants on the hydraulic properties of soils.

4. National R&D policy

The universities play a very important role in the R&D activities. This is emphasised by the plan to vitalise the geotechnical group at the Technical University of Denmark by internally increasing staff and resources. However, the universities at large are presently experiencing cut-downs due to (hopefully temporary) declining student interest and intake combined with general cost-saving initiatives.

Simultaneously the Danish Technical Research Council is being restructured both administratively and in terms of granting practice. Fewer sub-councils for evaluation of grants will mean that geotechnical engineering will appear as an even more inferior area than before. When this is coupled with a general trend within the last decade to channel the funding to Engineering research Centres and Framework programmes (in practise requiring major research groups and constituting >2/3 of the total funding) a proliferation of geotechnical engineering is urgently needed and cooperation with bordering disciplines and international partners is a must.

The latter will facilitate EU financing which ought to constitute a larger proportion of the Danish funding and is seen as one of the possibilities for the proliferation of our profession. Thus, a concerted effort on a European basis to provide a geotechnical voice in EU outlining significant areas of research for the benefit of society is vital in order to channel more EU funding into geotechnical engineering in the future.

At a national level the possibilities for geotechnical R&D are presently looking somewhat dire as the governmental focus on areas such as Information Technology and the focus on fast-tracking and design-and-construct contracts in our own field squeezes the geotechnical profession considerably. This may in turn lead to drastic changes in the structure between consulting and contracting companies and require new approaches for the enhancement of geotechnical services and for the preservation and not least improvement of the quality of these services.

In Denmark the advent of EUROCODES and accompanying standardisation work within field and laboratory testing is seen as a stepping stone to stronger internationalisation of the profession. And simultaneously presenting major challenges for inter-disciplinary cooperation within R&D in geotechnical engineering.

AGEP: Soil Mechanics papers

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