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Technical session 2e: Marine and transportation geotechnical engineering

Séances techniques 2e: Géotechnique marine et de transport

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1 INTRODUCTION

The Technical Session TS2e, run by the chairperson, Dr. Suzanne Lacasse assisted by the Secretary, Dr. Ohtsuka, involved the presentation of the General Report by Prof. Gomes Correia and four panel presentations following the schedule presented in Table 1.

Table 1 – Schedule of Technical Session TS2e
9/15/2005, Wednesday (10:30 -12:30)

Name	Presentation	Time (min.)
S. Lacasse, NGI, Norway	Introduction	5
A. Gomes Correia, Univ. Minho, Portugal	General report	30
G. Murray, SKM, New Zealand	Offshore technology	10
C. Athanasiu, Multiconsult, Norway	Stability of offshore foundations	10
S. Nazarian, Univ. Texas El Paso, USA	Quality management of pavements and role of integration	10
Takashi Tsuchida, Hiroshima Univ., Japan	Prediction of differential settlement in airport constructed on soft ground	10
B. Gebreselassie, Kassel Univ. Germany	High-speed railway settlements	10
Discussion		30
Summary		5

After the welcoming introduction by Dr. Suzanne Lacasse, Professor Gomes Correia presented the General Report (Gomes Correia & Lacasse, 2006) summarising the state-of-the-art on selected transportation and offshore foundation and the main points and findings from the technical papers in the session. Professor Gomes Correia also identified several open questions and research needs, including:

Offshore foundations:
- Foundation design of new installations.
- Suction anchors: Safety factor for plug failure during installation; uncertainties related to crack formations along active side of anchor; set up effects.
- Drag anchors: Validation of analytical values versus model prototype observations.
- Offshore geohazards: Risk assessment for underwater slides and other geohazards.

Pavements and railways:
- Material characterization: Cyclic and dynamic properties; ballast (interpretation with the theory of continuum medium?), micro/mechanics approach.
- What are the best tests to relate field, laboratory and design parameters?
- Prediction of settlements, influence on structure damage.
- Serviceability criteria – need for validation.
- Ballast track or ballastless track?

Some of these questions were debated by the panelists, covering some of the gaps identified in the general report. The debate was also entertained with the participants attending the session.

2 SUMMARY OF PANEL PRESENTATIONS AND DISCUSSIONS

2.1 *Offshore technology, by Grant Murray*

Key points for debate were chosen and illustrated with examples from papers in the session:
- What about offshore technology transfer?
- What about academic and practice?
- What are we measuring?
- Why are we testing?
- Comparisons between physical and computational results;
- Modeling and real life behaviour/performance: In this respect an important contribution was presented to this conference in the Theme Lecture at this ISSMGE conference on Offshore Geotechnical Engineering by Mark Randolph;
- Have we really achieved an advance in technology or rather new empiricism?
- The importance of cyclic loading and residual strength was also highlighted.

2.2 *Stability of offshore foundations, by Corneliu Athanasiu*

Considering the vast subject involving stability of offshore foundations, Dr. Athanasiu emphasized the important aspects that need to be accounted for in determining the load-bearing capacity of offshore foundations:

(1) The gradual increase in magnitude and complexity of the environmental loads. Consequently one important topic is the accumulation of pore water pressures under cyclic loading and the models and methods that can be used to determine the actual pore pressure left at any moment during and after a storm. Another important issue is to identify failure mechanisms and find methods of improving the load-carrying capacity. Issues proposed for discussion are presented in Table 1.

(2) Constructions at increasingly larger water depths. This is usually associated with the presence of very soft deposits of soil within the few metres under the sea-bed and also with frequent underwater landslides. An improved characterisation of the top soil properties and a consideration of both local and general stability close to the sea bed are needed (Table 2).

(3) Gradual increased occurrence of natural (geological, climatic) events (earthquakes, slides, flood, volcanoes), i.e. Geohazards. Consequently there is a need to improve our understanding of geohazard characteristics, to assess the risks and to improve the methods of modelling the mechanical processes involved (Table 3). These issues are also the main research directions of the International Centre of Geohazards (Norway) at NGI.

Table 1. Gradual increase in environmental load magnitude and complexity

Tendency	Topic	Papers relevant to the topic	Proposed discussion/questions/ relevant references
Gradual increase in environmental load magnitude and complexity	Soil behaviour under cyclic loading		Is the soil behaviour (pore pressure accumulation) the same under fully undrained and partly drained conditions? Do we need different types of tests (effect of principal stress rotation, magnitude and number of cycles that produce destructuration?
	Method to evaluate excess pore water pressure under cyclic loading	Hamre et al.	CYCPORE2 – uncoupled transient pore water pressure analysis; Jostad, Anderson & Tjelta (1997); SvanØ et al (1997)
	Identify failure mechanisms	Check, White & Bolton Valore & Zicareli Micic & Lo	Check, White & Bolton show that cyclic loading changes the failure mechanisms as compared to monotonic loading
	Methods to improve the capacity of offshore foundations		Does the electrokinetic treatment change the failure pattern (enlarge the volume of soil attached to the cylinder)? Will the improvement of load-bearing capacity remain the same under cyclic loads?

(4) Gradual increase in the awareness of the uncertainties involved in geotechnical predictions. The prediction of foundation behaviour - particularly that of offshore foundation - involves uncertainties due to a series of factors such as uncertainty in soil data and loads. It is increasingly important to adopt rational and "documentable" design approaches that point out and account for uncertainties involved in the design. Key issues to be discussed are presented in Table 4. The profession is facing today the situation that the analysis techniques and sophisticated laboratory testing methods are relatively more strongly developed than the capability to determine the reliability of in-situ soil parameters. It is important to develop databank for soil parameters in view of using the accumulated experience and results to improve the prediction of design parameters.

Table 2. Foundations at increasingly larger water depths

Tendency	Topic	Papers relevant to the topic	Proposed discussion/question
We install the subsea structures/ platforms at increasingly larger water depths	Need to identify and describe soft soil with very low shear strength and stiffness	Puech et al.	Shall we use an elasto-plastic model with anisotropy and destructuration to model the behaviour of soil deposit in the continental shelf of the Gulf of Guinea?
	Need for better field measurements of soil parameters	Strout & Sparrevik Tufenkjan & Thomson	Can measurements of pore water pressures at different levels be used to perform dissipation tests (to measure c_v)?
	Need to consider not only the (local) foundation stability but also general stability of the region (submarine slides)	Strout & Sparrevik	Can the measurements of pore water pressures at different levels help identify old slides (location of slip surfaces)?

Table 3. Increased frequency of natural events

Tendency	Topic	Papers relevant to the topic	Proposed discussion/question/ relevant references
Gradual increase in natural (geological, climatic) events (earthquakes, slides, flood, volcanoes), i.e geohazards	Trigger mechanisms	Puech et al.	How can we improve our knowledge and ability to identify triggers of different failures?
	Underwater slope stability	Kliner & Groznic	
	Identification of gas hydrates	Strout & Sparrevik	Nadim (2002)
	Identify actions and loads on offshore structures		

Table 4. Gradual increase in our awareness of the uncertainties involved in our predictions

Tendency	Topic	Papers relevant to the topic	Proposed discussion/question/relevant references
Gradual increase in our awareness of the uncertainties involved in our predictions	Uncertainties: loads, spatial variation of data, soil parameters, limitations of our calculation methods Include reliability analyses along with deterministic ones		Lacasse & Nadim (1994) How shall we present the soil investigation report to include data for probabilistic analyses? Include mean values, standard deviations, how many of standard deviations over/under mean value are maximum/minimum conceivable values of shear strength, stiffness modulus, etc? Do the terms "best estimate", "upper bound", "lower bound" have the same meaning for s_u= 1-2 kPa as for s_u=300 kPa? (Bye, 2005)

Mr. Knut H. Andersen from NGI also made a contribution from the floor on the importance of pre-shearing (pre-cycling at low shear stress levels) for the prediction of the cyclic behaviour of sands a higher shear stress levels. The panel agreed with this.

Prof. Verruijt contributed from the floor, by discussing the importance of estimating the excess pore water pressures built up during a storm loading. He referred to the paper of Hamre et al. presented in the Discussion Session 2e on Wednesday September the 14^{th} on Sakhalin platform: the platform was placed directly on a very thin layer of sand and a drainage system was conceived to reduce the accumulated pore pressures from the storm and to ensure thus the foundation stability to sliding. Prof. Verruijt questioned whether the foundation stability could be ensured by removing the sand layer instead of draining the excess pore pressures. Dr. Athanasiu answered that the reason for choosing drainage solution was to avoid the skirts (as needed when placing the foundation on the clay layer, under the removed sand layer), which would cause more difficult conditions for the dry dock construction phase.

2.3 *Quality management of pavements and role of integration, by Soheil Nazarian*

Professor Nazarian discussed the evaluation of the quality of pavement during construction and during the service life of the pavements, highlighting the role of integration.

In this framework the test procedures and equipments should (1) measure fundamental engineering properties, (2) be layer specific and (3) results in similar material properties in laboratory and in the field. Additionally, the test methods should be relatively inexpensive, nondestructive and automated. In this context, two main categories of popular nondestructive methods were mentioned: the deflection-based methods and the seismic-based methods. Advantages and drawbacks of some tests of these two categories were identified.

Professor Nazarian also referred to the importance of taking into account the nonlinear behaviour of materials in the analysis of test results. He illustrated the methodology for Seismic Modulus Analysis and Reduction (SMART) from data obtained with SASW methods, such as the seismic portable device.

The need for an integration process was illustrated. The integration combines back-calculated results, while also considering the strengths and weaknesses of each method. The process allows a most accurate determination of representative moduli of all pavements layers, as well as a best estimate of layer thicknesses.

2.4 *Prediction of differential settlement in airport constructed on soft ground, by Takashi Tsuchida*

Professor Tsuchida focused on the need to predict differential settlements due to nonuniformity of the soil profiles and the loading history, for example in airport projects. In large scale reclaimed lands, the prediction of differential settlements as well as the total settlement are necessary for the design of structures.

The causes of differential settlements in reclaimed land were summarized as:

Type A: differential settlement at the boundary between the foundation of structure and the ground.

Type B: differential settlement between the improved ground and non-improved ground.

Type C: differential settlements due to non-uniform soil profiles and/or different loading histories in a large area.

Professor Tsuchida stressed that since late 1980s, the airport construction projects on large scale reclaimed lands on soft clay has been promoted in Japan. The differential settlement of Type C became quite important for the design of airport pavements, and also to assess the serviceability of airport. In this context, important developments in the numerical simulation of differential settlements were achieved and applied in airport projects such as the Offshore Expansion Project of the Tokyo International Airport (TIA) and Kansai International Airport (KIA) (Hitachi, S. et al, 1995).

In these simulations, the nonuniformity of soil properties, variability of fills in the reclaimed land, three-dimensional stress distribution and the spatial auto-correlation of soil parameters were taken into consideration.

This framework was applied and illustrated for two practical projects:

(1) To the site of new Runway A of TIA, showing a good agreement between the results from the simulation and field observation as a whole.

(2) To the construction of the new Runway C in the 3rd stage of TIA. In this case the simulation method was used to determine the necessary depth of improvement of soft clay. Nine years after opening, 50-120 cm consolidation settlements took place in the new Runway C. However, no repair work was caused by the differential settlement, which indicates that the differential settlements were slightly less than those predicted by the method.

2.5 *High-speed railway settlements, by Berhane Gebreselassie*

Dr. Gebreselassie's presentation was prepared in co-authorship with Prof. Hans-George Kempfert and focused on two practical examples on concrete track systems.

To secure the serviceability, the functional safety and the driving comfort of a high speed railway, the settlements of the underground, subgrade, embankment, subbase, base and structure including bridge structures must remain within a permissible limit. This is especially important for the concrete slab track system, where the possibility of adjusting the settlement is very limited. Furthermore, one must bear in mind that it is not the settlement of individual elements of the railway in the longitudinal, transversal and depth directions that are of importance, but rather the settlement of the whole system along a stretch of the railway.

To illustrate how to deal with these aspects, two practical cases were detailed in the presentation:

(1) Settlement requirements of concrete track under high-speed railway traffic

To fulfil the settlement requirements of poor concrete slab track systems, the settlement of the elements of the railway track along the longitudinal direction should be estimated both in absolute terms and in terms of its development with time. These estimated settlements should be periodically compared with the measured settlements, to document whether the concrete track system can tolerate the settlements before the slab is built.

The main requirement of settlements for concrete track railway system after completion of the track system is that the residual settlement should not cause a change in the topographic position of the track, which may endanger the safety of the operation of the railway or may influence the availability of a particular stretch. Due to the system-dependent limited possibility of correction of the vertical deformations in the rail fixing points, the settlements should not exceed the maximum height correction after the construction of the track, e.g. 20 mm (for RHEDA type) less 5mm reserve settlement arising from dynamic effect of the railway transport (Vogel and Grübl, 1993). By a uniform settlement of the track system in a 20 m length of a railway, the allowable residual settlement amounts to two times the reduced correction value, i.e., 15 mm for RHEDA system. In exceptional cases, a maximum residual settlement up to 60 mm can be allowed, provided that it fulfils the comfort criteria:

$$R_a \geq 0.4 \cdot V_e^2 \tag{1}$$

where R_a is the radius of curvature in m and V_e is the design speed of the train, e.g., for V_e = 300 km/hr, the radius of curvature is 36000 m. Similarly, the deformation requirements in the transition zone between the track system on underground soil and the bridge for example as well as the deformation of the bridge itself can be found in Vogel and Grübl (1993), Jaup (2001), DS 804 (B6) (2000), Kempfert et al. (2002), etc.

(2) Heave due to swelling of the underground

Concrete track systems are very sensitive to heave due to swelling of soils. Limited remediation scenarios exist in such system. Therefore, it is important to predict the swelling potential of the underground at the time of operation of the railway, so that construction measures can be implemented before the construction of the concrete track.

Railway lines may pass through a soil or rocks that are liable to swelling such as overconsolidated clays, e.g. flint, and diagenetically solidified clay rocks, e.g. opaline rock, amaltheen rock etc. Similar to the rigid requirements of minimum settlements for a concrete slab track system, the swelling problem demands a dependable solution for the prediction of the maximum heave and the evolution of displacement with time, as well as a measure to control such kind of heave.

The maximum heave can be estimated among others from the equation recommended by Grob (1972) or Wolffersdorf et al. (2002).

$$\varepsilon_{z\infty}^{q} = -C_b \cdot \ln\left(\frac{\sigma_{z\infty}}{\sigma_{z0}}\right) \qquad (2)$$

where σ_{zo} is the maximum vertical pressure where the soil or rock is prevented from swelling, and C_b is the swelling index which indicates the dependency of the heave on the vertical stresses. The two parameters σ_{zo} and C_b required for the swelling law can be determined in the laboratory. Similarly, the evolution of heave with time can be estimated again from the equation recommended by Kiehl (1990) among others.

$$\varepsilon_{t}^{q} = -C_b \cdot \ln\left(\frac{\sigma_{z\infty}}{\sigma_{z0}}\right)\left[1-\exp\left(\frac{\hat{t}}{\eta_q}\right)\right] \qquad (3a)$$

$$\hat{t} = t \cdot \left(\frac{d}{D}\right)^{n} \qquad (3b)$$

where the time factor η_q can be determined from swelling potential test in the laboratory; *d* represents the thickness of the laboratory specimen and D the thickness of the soil layer in the field. The exponent *n* can be determined from the calibration of the evolution of swelling to measured heave, e.g. extensiometers.

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