Proceedings of the 16th International Conference on Soil Mechanics and Geotechnical Engineering

doi:10.3233/978-1-61499-656-9-3145

Technical session 1b: Laboratory testing (II): Strength, large deformation and hydraulic properties

Séances techniques 1b: Tests de laboratoire (II): Résistance, grandes déformations et propriétés hydrauliques

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1 INTRODUCTION

Technical Session (TS) 1b entitled “Laboratory Testing II: Strength, Large Deformation and Hydraulic Properties” is comprised of a total of thirty nine papers addressing a wide range of topics concerning the laboratory testing. The session was held on 13th September, 2005 at 13:30-15:30 with Professor Hideki Ohta, Tokyo Institute of Technology, Japan, in the chair. The session began with introducing all names of paper authors. They were invited on the stage to be praised for their contribution to this session.

The general report was made by Professor Euduardo Alonso, UPC, Barcelona, Spain, for about 30 minutes. After his explanation of current research topics on the laboratory testing by citing all papers which had been submitted to this session, five panelists and two discussers ascended to the platform for their presentations.

2 PRESENTATIONS BY PANELISTS AND DISCUSSERS

Panelists in this session were Prof. David Muir Wood (UK), Prof. Jacques Desrues (France), Prof. Richard Finno (USA), Prof. Chu Jian (Singapore) and Dr.Yoichi Watabe (Japan). And discussers were Prof. Hideki Ohta (Japan) and Prof. Jiro Kuwano (Japan). The discussion topics were carefully determined so as to encourage the discussion from the floor. Topics chosen for discussion were as follows.

- The effect of recent stress history on current incremental stiffness over small to medium strains by investigating stress response envelopes
- Some recent advances in the use of X-Ray CT scanners to investigate the precise characterization of the internal structure of soil specimens
- The development of cracks, the transition from diffuse to localized deformation in clays and other cohesive materials
- Recent experimental results related to the definition of limit states based on drained stress probes
- The failure of loose granular soil slopes triggered by instability or static liquefaction occurring under undrained conditions
- Long term consolidation associated with the Kansai International Airport and the Leaning Tower of Pisa

Panelists and discussers ascended to the platform in the following order.

Professor David Muir Wood (UK), *Multiaxial stress response envelopes for sand*

Studies of particle assemblies show that the elastic region for sands is of negligible size. Rational testing in support of development of constitutive models can most usefully explore the effect of recent stress history on current incremental stiffness over small to medium strains by investigating stress response envelopes. A flexible boundary true triaxial apparatus has been used to conduct series of deviatoric stress probes at constant mean stress and with several different common histories. Stress response envelopes have been constructed for each history. The shape of the envelopes evolves as the magnitude of the increment of strain from the common history point increases. The effect of recent history is progressively lost. Some success has been obtained in describing the observations using a kinematic hardening/bounding surface constitutive model.

Prof. Hideki Ohta (Japan), *Equivalent pre-consolidation pressure for compacted soils*

The similarity of mechanical behavior of compacted soils with that of overconsolidated clays encourages introducing the equivalent pre-consolidation pressure for compacted soils. Then, an elasto-plastic constitutive model for clays is applicable to describing the mechanical behavior of compacted soils by using the equivalent pre-consolidation pressure. It is discussed how the equivalent pre-consolidation pressure can be specified and determined from laboratory tests for compacted soils. And a practical application of the soil/water coupled elasto-plastic F.E. technique to an earth fill dam is presented.

Prof. Jiro Kuwano (Japan), *Effects of shear stress history on yielding of dense Toyoura sand in p'-constant shear plane*

Effects of shear stress history on yielding characteristics of dense Toyoura sand were investigated. It is shown that the yielding behavior in p'-constant plane is characterized, especially at small strain level, by introducing two sub yield surfaces Y1 and Y2 inside the conventional large-scale yield surface, Y3. Y1 yield surface is mobile with current stress state point. It changes the shape into elliptical as it moves to anisotropic stress state. Its size does not change. Likewise, Y2 yield surface is also mobile with the current stress state point and changes the shape into elliptical as it moves to anisotropic stress state. It becomes larger after the loading-unloading stress history. In contrast, Y3 yield surface is comparatively immobile. It stays around the isotropic stress state point. It becomes larger when it intersected by the current stress point. It shows isotropic hardening. The direction of the plastic shear strain increment vector is not normal to Y2, but it becomes normal to Y3 for the further shearing. Therefore, associated flow rule can be applied to Y3.

Prof. Jacques Desrues (France), *On the use of CT scanners in Laboratory testing for soils*

Some recent advances in the use of X-Ray CT scanners in geomechanics are presented. CT scans allow to get more precise characterization of the internal structure of soil specimens submitted to laboratory tests, especially in large deformation and near rupture. In sand and other granular materials, it is possible to characterize the grains themselves. In clays and other cohesive materials, the development of cracks can be followed in detail. The transition from diffuse to localized deformation can be studied. Some results will be presented to illustrate the interest of these new techniques.

Prof. Richard Finno (USA), *Limit state of a fresh water glacial clay*

Recent experimental results are summarized related to the definition of limit states based on drained stress probes. Fresh water, lightly overconsolidated glacial clay samples used in the study were cut from blocks retrieved from a deep supported excavation. Experimental procedures and methods of analysis are summarized, and practical implications of the results are presented.

Prof. Chu Jian (Singapore), *Instability of sand*

As static liquefaction or instability behaviour of sand is observed mainly for loose sand under undrained conditions, the failure of loose granular soil slopes is often considered to be triggered by instability or static liquefaction occurring under undrained conditions. However, there are cases where instability occurred under essentially drained conditions. Failure mechanisms related to a redistribution of void ratio within a globally undrained sand layer and spreading of excess pore pressure with global volume changes have also been envisaged.

Laboratory data are presented to show that both loose and dense sand can become unstable under completely drained or non-undrained (i.e., other than undrained) conditions. Different types of instabilities and its engineering implications are discussed.

Dr. Yoichi Watabe (Japan), *Learning from long term consolidation test*

Long term consolidation is a very important geotechnical issue, in particular, in the Kansai International Airport and the Leaning Tower of Pisa. Clay samples collected by Japanese standard method (thin-walled tube sampler with fixed piston) from both sites were tested: (1) CRS consolidation test to evaluate basic characteristics of consolidation (e-log p, cv), (2) long-term consolidation test to evaluate long-term consolidation characteristics for laboratory specimen (60 mm in diameter and 20 mm in thickness, double drainage), and (3) inter-connected consolidation test corresponding to different specimen thickness (20 and 100 mm in thickness, single drainage) to study consolidation similarity law on thickness. These laboratory test results are presented to discuss about the long term consolidation.

3 FLOOR DISCUSSIONS AND QUESTIONS

Presentations by panelists and discussers were followed by the floor discussion. The first question from the floor was on the shape of yielding surface and the kinematic characteristics of it. The boundary between elastic and plastic behavior was a still hot topic.

Many questions on the CT scan were asked to Prof. Desrues. The size of the specimen applicable depends on the type of the CT scan used. Medical scanners can take large specimens of 10cm in diameter. Micro CT and tomography applications on synchrotron beamlines take much smaller specimens, typically 10 mm in diameter. Generally, high resolution can be achieved only on relatively small specimens. Another question was on the shear band observation in loose specimens in which dilative deformation hardly takes place. The answer for it was as follows. In loose specimens, there can be very little dilatancy, virtually zero, but still some structuration appears in the pictures due to small local volumetric strains, and one can recognize the same kind of localization patterns that have been shown in dense specimens. More importantly, the extension of digital image correlation to 3D makes it possible to measure the 3D displacement and strain fields, without any reference to local density change. This is a completely new way of using tomography.

Two questions were made regarding the presentation by Prof. Chu Jian. The first question was asked by Prof J.H. Yin, Hong Kong Polytechnic Univ., on the differences between strain softening and instability. The answer by Prof. Chu Jian was as follows. Strain softening and instability are two different phenomena. Strain softening refers to a process in which the shear stress (or shearing resistance) reduces gradually after a peak shear stress has attained. This process can occur without increasing the strain rate. Experimentally, strain softening is normally observed under a deformation controlled loading mode. Instability refers to a process in which the strain rate increases suddenly without or without reducing the stress or load. Experimentally, instability can only occur under load controlled loading mode. To study instability or liquefaction, tests under loading controlled loading mode should be conducted. The conditions for the occurrence of strain softening and instability may be similar under some conditions, but not all the time. The second question from the floor was that the drained instability should be the same as undrained instability and asked whether instability can be predicted using effective stress. Prof. Chu Jian commented that undrained instability may not be the same as drained instability. For example, drained instability can occur for dense sand, but not undrained instability. Although, there are some similarities in the conditions in which drained and undrained instability would occur, in general drained and undrained instability should be studied separately. Instability can be predicted using effective stress. In his presentation, all the types of instabilities are interpreted in terms of effective stress.

As to the long term consolidation, Prof. Kakuichiro Adachi asked from the floor that 'what is the real factor, when the reason of which the secondary consolidation behavior is not diatoms?' Dr. Watabe answered as follows. In this study, it was denied that the diatom was a factor for the significant secondary consolidation. Probably, calcium carbonate is a real factor for it. The next question was by Prof. Jian-Hua Yin on pore water pressure change during the secondary consolidation process. That is, usually the pore pressure slightly increases at the beginning of test; however, this was not observed in the test. Is there any reason? To this question, Dr. Watabe commented that 'the delayed pore pressure increase was observed when a specimen had small holes resulted by marine life activities or micro-cracks. Since specimens were selected very carefully taking account of it, pore pressure increase was not observed.'

Also, other fruitful discussions were made in this session. However, this secretary could not memorize all of their names and comments and he could not introduce them here. He deeply apologizes for it.

Finally, during a period of several months before the conference, this general reporter, these five panelists and two discussers who made presentation in this session devotedly helped the preparation and led this session to a success. In such a preparation process, this general reporter sent some comments which he got in his writing the general report. At the end, this secretary would like to show his comments here. They would be helpful and useful for the future development in this research field.

3.1 *Unsaturated soils*

- In compacted soils, what is the effect of the initial structure and its subsequent modifications induced by suction changes (drying or wetting after compaction) on the soil response during the operational stage of the compacted structure?
- Are there alternative variables to the classic ones of water content and dry density to describe more properly a compacted soil?
- Effect of previous stress and suction path on the water retention characteristics of a given soil
- What is the reliability of current empirical approaches to determine the water retention curve on the basis of basic identification data? How can it be improved?
- What is the reliability of current empirical approaches to determine collapse and swelling potential of natural soils?

3.2 *Clay soils, long term effect*

- In heterogeneous soft sediments (such as the soils in the Venezia area, described by Cola and Simonini) is there a chance for a conventional soil investigation (samples + laboratory tests) to lead to a reliable model for soil compression behaviour in the short and long term?
- Are the creep susceptibility diagrams relating creep rate and deviatoric stress ratio (Lacasse ad Berre's paper) sufficiently general to provide a guide for creep susceptibility?

3.3 *Granular soils*

- Sand looses the memory of the initial density as the confining stress increases. This behaviour is attributed to the breakage of particles. Size effects make these phenomena increasingly relevant as the grain size increases. But, other factors such as grain petrology, grain shape and grain size distribution control particle breakage. With this background, are there rules to predict the confining stress which marks the transition to "clay like" behaviour other than expensive laboratory testing?
- Since particle breakage is the physical phenomena controlling sand static behaviour at high confining stress but also cyclic behaviour of other granular materials such as gravel, shouldn't it be explicitly or implicitly incorporated into frameworks for the behaviour of granular aggregates?
- Is the state parameter ψ enough to describe for practical purposes, the static undrained behaviour of sands with variables amounts of fines?
- Can the previous history of loading be incorporated in criteria for undrained cyclic mobility in a simple way?

3.4 *Soil mixtures and soil design*

- What are the most informative identification properties of components in order to predict the geotechnical properties of a soil mixture? Are there suggested procedures to predict the resulting properties other than direct testing?

3.5 *Chemo-mechanical interactions*

- Is there a simple consistent framework to interpret the effect of pore water chemistry on the mechanical behaviour of clay soils?