GEOASIA Bulletin No.5

ALL SOILS ALL STATES ALL ROUND

GEO-*A*NALY*S*IS *I*NTEGR*A*TION

For finding soil deformation and collapse in sandy, intermediate and clayey soils, and for static or dynamic interests

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Edited by *GEOASIA* Research Society Office

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Message from the Society President

Where were you, and what were you doing, at 2:46 p.m. on March 11? I can recall times of having joked to students "A subduction type earthquake has a long period and is said to go on for more than two minutes – the time it takes to smoke a cigarette," but I never imagined I would personally have the experience of being caught on the eighth floor of a steel structure building in Tokyo swaying back and forth from one side to the other for all of five minutes. I hope and pray that no one came to harm in the earthquake, but if any of our members did, please let us know about it.

As we are aware, one upshot of this earthquake was a rude shaking of public confidence in seismic science. One scholar known for his part in establishing the standard prediction formula "an x percent probability of occurring in the next 30 years" is on record as being "ashamed of the unknowns that made it impossible to forecast this situation." But even if all the "unknowns" referred to by this scholar could have been filled in, would the earthquake have been any more predictable? That is what everyone wants to know. Even when it is beyond doubt that a quake is coming, how far is it possible to "predict" or "forecast" its arrival? That, I think, is a point that ought to have been better explained to the public.

As we can all see, however, this is a problem calling for more than a jibe at seismic science. It is a fact that our own area of geomechanics and geotechnology is on equally shaky ground, as are the support efforts of our researchers and technicians. That is the aspect I want to think about briefly here. For what follows, the reader is asked to keep in mind the ground liquefaction damage that affected extensive areas of northeastern Kanto, most notably Urayasu.

The first thought occurring to the people affected by the disaster was the elementary scientific question "Why did ground liquefaction occur in this area?" Questions like "Who is to blame?" come later. Whether people regard the loss they have suffered as just bad luck or see it as being somebody's fault, the point they need to be satisfied about first is the scientific understanding of the phenomenon that has occurred. This is an intellectual demand that arises for experts and non-experts alike, from the mere fact of being human. The first responsibility facing scholars and technicians in the geomechanical and geotechnical fields now is how to supply an accurate answer in their respective languages of science and mechanics. For the truth is that of all soil behaviors liquefaction is the one most removed from the standard topics of consolidation and bearing capacity found in textbooks of soil mechanics. For a long time, it has been conspicuous through its absence from the common stock of perceptions shared by specialists. Putting it more bluntly, the authorities in sand liquefaction for many years past have been senior academics wholly unable to calculate the compaction of loose sand. What first needs to be made clear to

Photo 1 Liquefaction damage due to the 2011 off the Pacific coast of Tohoku Earthquake in Sawara city. (photo by Kentaro Nakai on April 3, 2011.)

the residents of Urayasu, then, is the primitive reality of the present state of knowledge: no shared terminology can yet be said to exist in academic societies for describing the mechanism of liquefaction. But if earthquake prediction is so fraught with problems, surely it cannot be right to stay in the same old rut of making it serve as a hold-all term in public information. On top of which, one is also tempted to add that citizens are no longer prepared to go on accepting the stance statements resorted to by specialists of the sort "There is nothing we don't understand about liquefaction nowadays," or "This damage simply resulted from not keeping to design standards."

The ***GEOASIA*** Research Society and the Geomechanics Group at Nagoya University have already decided to put their research funds into a soil survey of the thick deposit of soft clay beneath the liquefied sand layer in Urayasu City. This decision is prompted by a perception that the liquefaction that occurred there is far from well understood, and is based on the two theoretical hypotheses that (1) liquefaction was caused by repeated long-period shearing in a soil containing many fine particles and (2) the existence of the underlying soft clay layer must have played an important part. The Japanese Geotechnical Society has traditionally conducted damage surveys in this way whenever a natural disaster occurs, and while self-satisfaction and complacency are obviously out of place, I am nonetheless gratified as president of the ***GEOASIA*** Research Society to see this admirable investigative activity being undertaken with a will to discover new facts and clarify obscure phenomena, especially at a time when it might have been feared that the passing of years would lead to a sudden flagging of energy. In the search for true knowledge, the question "Experiments or Theory first?" has long stood as a banner inscription for new initiatives in the Geomechanics at Nagoya. The time has come to raise this banner again and make a concerted advance into the heart of the disputed territory. I trust that members will acquit themselves creditably in this latest venture for the furtherance of geomechanics.

Akira Asaoka,
Senior research advisor, the Association for the Development of Earthquake Prediction (reg. foundation);
Emeritus professor, Nagoya University

Feature article: Influence of the deeper soil-layer composition on the liquefaction of a sandy surface soil containing many fine particles

The 2011 off the Pacific coast of Tohoku Earthquake resulted in ground liquefaction in extensive areas of reclaimed and other coastal land along the shores of Tokyo Bay, especially in the city of Urayasu. Two characteristics of special note were ① that although the focus was a good 450km away and the maximum surface accelerations as recorded on K-net and elsewhere came to no more than about 100-200gal, the long wave period led to severe liquefaction, and ② that this occurred in sandy soils containing many fine particles. The cause of the soil damage has so far not been clarified, although many references have been made to the duration of the seismic motion. Fig. 1 shows the layer composition of a soil section in Urayasu. While the soft clay layer on the lightly damaged landward side has a thickness of only 10m or so, the further one looks to the coastward side where the devastation occurred, the thicker the layer becomes. With this last consideration in mind, an elastoplastic seismic response analysis of the multilayered soil system was used to show how, in conjunction with the protracted duration of the motion, the presence of this sedimentary layer of soft clay in the ground beneath the liquefied layer was importantly implicated in the liquefaction effect produced in the silty sand.

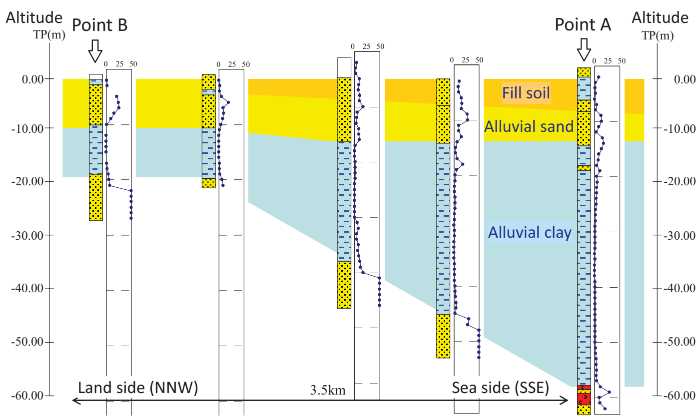

Fig. 1 Layer composition of ground in Urayasu
(using data from the Regional Environment Information Bank)

As shown in Fig. 1, a one-dimensional model in the depth direction was used to investigate the influence of the underlying ground composition (that is, the influence of layer and soil variations) on the liquefaction of the silty sand in the surface layer. The seismic wave applied to the seismic bedrock in earthquake was selected to fit observed Vs values taken from underground Kik-net measurements in Chiba Prefecture. The greatest accelerations come to only a few tens of gals.

Fig. 2 shows the acceleration responses and Fourier amplitude spectra at the respective layer boundaries below point A. In the soft clay layer, a remarkable amplification is found in the long-period range of the spectrum, especially. Fig. 3 shows the excess pore water pressure ratio at mid depth in the surface layer, against time. From practical experience, liquefaction is known to occur when this ratio goes above 0.95. From the figure it can be seen to undergo an abrupt rise in the vicinity of the maximum acceleration (120s). After that, although there is some slowing down in the rate of increase, the persistence of the long-period wave causes the excess pore water pressure ratio to approach progressively closer to 1.0, finally setting off the process of liquefaction. Also included in Fig. 3 are the results for two alternatively assumed cases, one in which the thickness of the clay layer at B is smaller, and another in which the layer of soft clay at A is replaced by a layer of dense (i.e., non-liquefying) sand. In the case where the clay layer is thinner, the rise in the excess pore water pressure ratio also remains small, making it difficult for liquefaction to occur; in the case of the sandy soil layer, the acceleration wave is not amplified as it is in the soft clay (the result of the analysis is omitted) so that the liquefaction threshold is not reached.

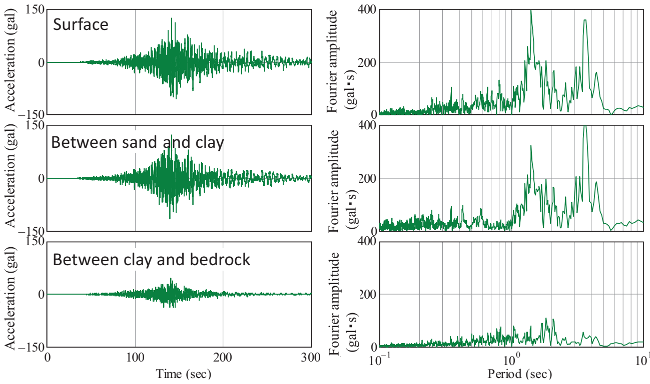

Fig. 2 Acceleration responses at the respective layer boundaries beneath ground point A

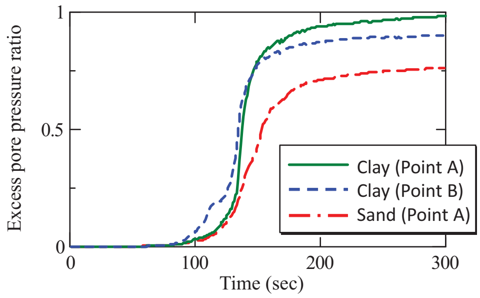

Fig. 3.Time variation of excess pore water pressure ratio in the ground surface layer, with respect to

In previous methods of assessment for liquefaction, in use over the past forty years or so, only the "soil property" was taken into account, with nothing directly said about the duration period or the layer composition of the ground beneath. The necessity of an updated numerical soil mechanics based on the dynamics of elastoplasticity deserves to be stressed.

Report of awards earned using the *GEOASIA* geo-analysis technology

The three following awards were gained in the academic year 2010 for research achievements making use of the ***GEOASIA*** geo-analysis technology.

【*2010 Best Paper award of JGS*】
Kawai, T., Ishimaru, M., Noda, T. and Asaoka A. (2010): A study of settlements of the backfill ground around a rigid structure during an earthquake by centrifuge tests and by a FE simulation (*Japanese Geotechnical Journal*, Vol.5, No.1, pp.45-59)

【*2010 Award for the encouragement of research of JGS*】
Takeuchi, H.: Co-seismic and Post-seismic Behavior of an Alternately Layered Sand-clay Ground and Embankment System Accompanied by Soil Disturbance (*Soils and Foundations*, Vol.49, No.5, pp.739-756)

【*2011 Best paper award of JGS for young presenter at an international conference*】
Shiina, T.: Progressive Failure of a Cement-Treated Ground in Bearing Capacity Problem
(*Proceedings of the 14th Asian Regional Conference on Soil Mechanics and Geotechnical Engineering*)

Report of activities in Academic Year 2011

① Prediction of settlement associated with an embankment load on a soft ground in Vietnam

On a visit to Vietnam in October, 2010, Society President Asaoka inspected a site where an embankment had been raised on a soft ground, resulting in a pattern of settlement (involving secondary consolidation) difficult to treat using the “Asaoka method of settlement prediction.” While there, he also delivered a lecture on the mechanism of secondary consolidation with reference to a similar site in Japan, engaged in a dialog with the site technicians, and discussed ways of predicting the possible future settlement at the site and of deciding on countermeasures.

Photo 2 The President’s lecture (Ho Chi Minh City)

Photo 3 In dialog with the Vietnamese technicians

② Flow of soil through a system of piles, with a discussion of the effect of the soil reaction on the piles: Simulation of a model experiment

In this numerical study of the effect of the soil reaction on a system of piles relocated in the same layer of earth (Fig. 4 shows a section perpendicular to a pile, as viewed from above), it was shown that (1) since the rate of migration of the pore water through the soil varies in response to the loading rate, slower loading will lead to a progressively greater soil reaction, and (2) since a staged change in the loading rate leads first to a rise in the load exerted by the relocation of the piles and second, after later consolidation, to a rise in the constraining pressure on the front face of the pile, the combined effect here too will be a gradual increase in the soil reaction.

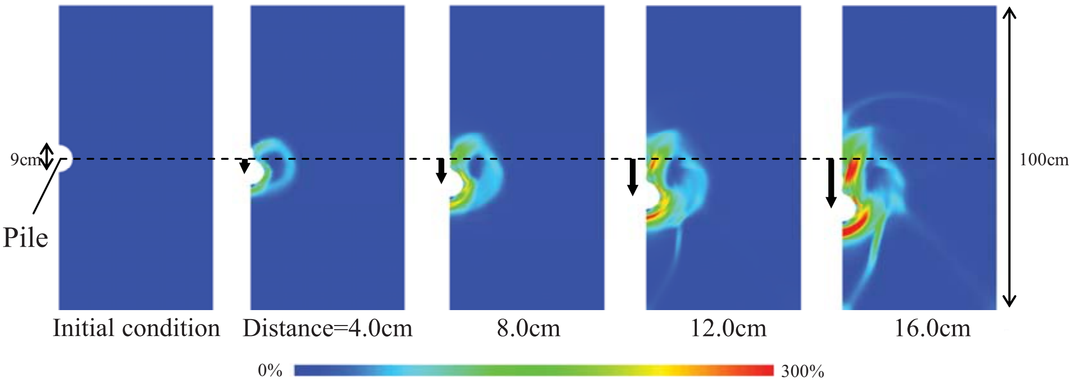

Fig. 4 Variation in shear strain over time

③ Influence of the liquefied layer thickness on the seismic stability of a column assembled from steel plates

A numerical analysis was performed for a seismic stability assessment of a lightweight column made up of steel plates and erected on a sandy ground with a high risk of liquefaction. It was found that where the liquefied layer is thick the horizontal displacement of the structure will be small due to the loss in acceleration, but where the layer is thin the damping effect will be less so that the structure on top will be exposed to powerful shaking. Seismic stability will therefore be poor.

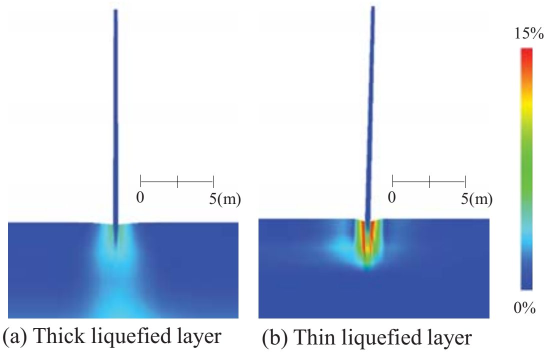

Fig. 5 Distribution of shear strains 10 years after earthquake occurrence

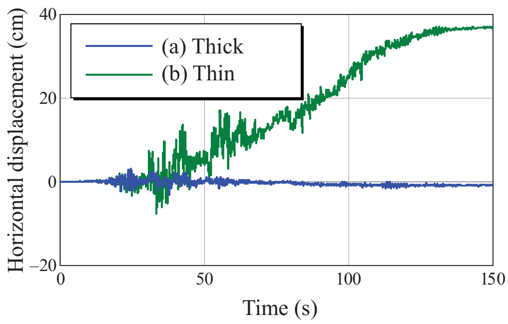

Fig. 6 Horizontal displacement at the top of the structure at the time of the earthquake

Principal publications etc. in Academic Year 2010 (including the first half of AY 2011)

Academic papers:

【*Soils and Foundations*】

Prediction of settlement in natural deposited clay ground with risk of large residual settlement due to embankment loading, Vol.51, No.1 pp.133-149.

【*Japanese Geotechnical Journal*】

A means for assessing the seismic stability of a temporary structure sited on soft ground and preventing its collapse, Vol.5, No.3, pp.499-510.

International conferences:

【*International Conference on Computational & Experimental Engineering and Sciences, ICCES'11* (China, Nanjing, March 2011)】

Seismic stability assessment of a steel plate built up column erected on a liquefiable soft ground.

【*The 14th Asian Regional Conference on Soil Mechanics and Geotechnical Engineering, 14ARC* (China, Hong Kong, May 2011)】

① Co- and post-seismic behaviors of embankment-inclined ground systems, No.238 (CD-ROM).
② Seismic analysis of reclaimed ground with dredged soil, No.251 (CD-ROM).
③ Anti-seismic mechanism of a sandy ground improved by the SCP method, No.273 (CD-ROM).
④ Numerical study on the seismic assessment of coastal reclaimed ground, No.278 (CD-ROM).

Domestic conferences:

【*65rd Japan Society of Civil Engineers 2010Annual Meeting* (Sapporo, September 2010) 】3papers.
【*47th Japan National conference on Geotechnical Engineering* (Kobe, July 2011) 】8papers.
【*16th Conference of the Japan Society for Computational Engineering and Science* (Kashiwa, May 2011) 】1paper
【*20th Technical Report conference of Investigation, Design and Construction* (Nagoya, June 2011)】 1paper
【*23rd Chubu Geotechnical Symposium* (Nagoya, August 2011)】 3papers

Japan Geoscience Union

【*Meeting 2011* (Makuhari, May 2011)】

An attempt to replicate the so called "trampoline effect" in computational geomechanics.

Main Forthcoming Activities in 2011

This year the Society plans to contribute further to the advancement of seismic geomechanics and geotechnology through an expansion in the scope of its surveying and research activities carried out with the ***GEOASIA*** analysis tool. An intended part of this expansion, from this year on, will be the publication of research achievements not only, as in the past, in journals of geomechanics and geotechnology such as *Soils and Foundation*, but also in the seismology field represented by bodies such as Seismological Society of Japan. In addition, in cooperation with the Geomechanics Group at Nagoya University, a soil survey will be undertaken at Urayasu in Chiba Prefecture, an area which sustained considerable damage from liquefaction in the 2011 off the Pacific coast of Tohoku Earthquake. The aim here will be to clarify the mechanism of liquefaction. The Society will also continue with its commissioned research and surveying projects, employing the ***GEOASIA*** analysis technology in seismic reassessments, in the detection of weak spots requiring reinforcement, in considerations of the sort of soil reinforcement technology required, and, more generally, in all areas contributing to the alleviation of soil-related disasters.

Another branch of activity carried on by members of the Society is the provision of training courses, request classes, public lectures and public relation activities for the purposes of making ***GEOASIA*** geoanalysis more widely known and of training up new users through the ***GEOASIA*** MASTER program. Similarly, it is planned to continue study group sessions in connection with the publication of Society President Asaoka's geomechanics and geotechnology textbooks.

Editorial Afterword

The 2011 off the Pacific coast of Tohoku Earthquake that struck on March 11 set off seismic motions and tsunamis that caused massive ground devastation and brought losses to huge numbers of people. We express our deep sorrow for the many who lost their lives in the disaster, and extend our heartfelt sympathy to all those who suffered the privations of evacuation. Through the use of the ***GEOASIA*** analysis tool to perform commissioned survey and research tasks, to supply information and technical guidance, and to spread and develop the technology itself, this Society will go on devoting its efforts to the making of a national soil base that offers security against earthquakes. To that end, we ask all of our members for their continuing support.

(Mutsumi Tashiro, secretariat, ***GEOASIA*** Research Society)

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