GEOASIA Bulletin No.10

ALL SOILS ALL STATES ALL ROUND
GEO-ANALYSIS INTEGRATION

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

Issued August 26, 2016

Edited by *GEOASIA* Research Society Office

Furo-cho, Chikusa-ku, Nagoya, 464-8603, Japan TEL: +81-(0)52-789-3834

FAX: +81-(0)52-789-3836 E-mail: office@geoasia.jp URL: http://www.geoasia.jp

Message from the Society President

Counting from August 2006, when the ***GEOASIA*** Research Society was registered as a private organization, we can say (in August 2016) that it has reached its tenth birthday, making this Issue 10 of the *Bulletin*. But I wish to take this occasion of my tenth President's Message to look a little way further back still. It may make my message a bit long, but I hope it can be forgiven.

All of the basics for the underlying framework of the ***GEOASIA*** geotechnical analysis model were already in place in a doctoral thesis by Professor Toshihiro Noda, At the time a third-year doctoral student, with the (Japanese) title: "A Study on Behavior of Saturated Clay near/at Critical State and Soil-Water Coupled Finite Deformation Analysis." This was in March 1994. In this paper, under the constraint of no volume change asserted in Darcy's law, Noda, using an effective stress principle (for soil -water coupling), succeeded in substituting an incremental constitutive equation for elastoplasticity (the Cam-Clay model) into an equation for the equilibrium of incremental forces, thus opening a way to a flawless and exhaustive analysis of all conceivable non-static problems of normally consolidated clay from deformation to collapse, and also for post-collapse behaviors. This was achieved through a fusion of material and geometrical nonlinearities. Later the same year (1994), with the additional introduction of a subloading surface, an exhaustive analysis was made possible for all behaviors of overconsolidated clay. Having come so far so fast, no one would have been surprised if fundamental geotechnical research at Nagoya University had paused there for a while to take things more gently.

But as it was, the Hanshin / Awaji area around Kobe was rudely hit on January 17, 1995 by the 1995 Southern Hyogo Prefecture Earthquake. At the sight of a major city in flames after a seismic shock that hit it from directly beneath, we could only stand and stare while the feeling sank in: Is this all that our past soil mechanics was worth? Defeatism was in the air: "Faced with a real earthquake, what was the point of it all?" But at the same time – this may have been a personal impression but it was what I felt – there seemed to be a surge of youthful energy taking hold of geotechnical research in Nagoya University and pushing for its renewal. With the new concept of the superloading surface, developed at the end of 1997, the crucial distinction between sand and clay soils seemed to have come clear to everyone in the research group, and from that point on, led by the work of Assistant Professor Noda (as he now was), the old formula of the equilibrium of forces came to be replaced by an equation of motion. Now all was ready at last, to use a metaphor, for the heavy tiller to be flung round, leaving Nagoya University's geotechnical crew to sail off on their own bold course across wild but open seas bound for realms of dynamic problem solution. By 2005, just ten years on from the Hanshin / Awaji Earthquake catastrophe, they were in position to receive ¥50m in competitive research funding from the Ministry of Land, Infrastructure, Transport and Tourism with a proposal for seismic evaluations of manmade islands and coastal revetments constructed of intermediate sand/clay soils and for soil reinforcement technologies for the control of liquefaction and land slumps. The year after that saw the launch of the ***GEOASIA*** Research Society. All of the terms highlighted above in bold can be brought together in the descriptive formula from which the name ***GEOASIA*** derives: "All SOILS ALL ROUND ALL STATES ***GEO-A***NALY***S***IS ***I***NTEGR***A***TION."

Developments since then can be found summarized in detail in the ten issues of the ***GEOASIA*** Research Society *Bulletin*. From the contents, it is apparent how much further the results have gone in the ten years since the Society's foundation than in the preceding decade from the 1995 Hanshin / Awaji Earthquake to 2005. For example:

① The development of an unsaturated earth / unsaturated foundation analysis based on the analysis of a three-phase system taking in air, water and soil skeleton,

② A further refinement of the constitutive equation of elastoplasticity through the inclusion of a combined loading surface,

③ An extension in the area of applicability for coupled analysis as a result of a full formulation.

④ 2-D and 3-D calculations of a surface wave and recreation of a long-frequency long-duration seismic movement of high intensity,

⑤ Inverse analysis of a strong seismic reading obtained from a non-linear surface-layer ground response and an estimate of the seismic movement that gave rise to it,

⑥ The development of a macro-element method capable of taking account of well resistance,

⑦ A seismic diagnosis based on the model analysis of an earth-built or similar structure.

These developments, along with others, were all achieved in our past two or three years of research, yet they all involve study objects and aspects of content that would have been unthinkable ten years ago, It is because these research attainments are all so reliable taken individually that each of them is able to function successfully as a springboard to the next. Thus one creation gives birth to another, generating a virtuous cycle that has sustained itself for over 10 years. Example ① above, the technology for unsaturated foundation analysis in a three-phase coupling system, which goes back to 2015, has become the object of a second patent providing new financial support for the ***GEOASIA*** Research Society along with the earlier first patent for the analysis tool designed for a two-phase water-soil system. Armed with this new analysis instrument, solutions can be expected not only for unsaturated levee and seawall problems along rivers and coasts but also for cases like that of a 90m high mudstone embankment carrying the New Tomei highway across wetland, a structure that is vulnerable to deterioration through slaking. The new analysis tool can show what behavior to expect from such a structure upon the occurrence of an earthquake.

It has been widely supposed since the Hanshin / Awaji Earthquake that Japan is entering a distinctly active seismic phase. There are many seismologists and volcanologists who go so far as to say that "21st century Japan closely resembles the Japan that went through tectonic changes in the 9th century." If we align the Great East Japan Pacific Offshore Earthquake of 2011 with the Jogan Tsunami and Earthquake of 869, maintaining the parallel we find that the 2020 Tokyo Olympics year matches up with the Sobo Musashi Earthquake of 878 (which struck from directly below present Tokyo), and that 2029 would correspond to 887, the year of the Ninna Earthquake (a connected triple occurrence of the Nankai Trough Earthquake). Even dismissing this formalistic way of superimposing today's dates on past 9th century ones, an estimate based on "regularities in the active and quiescent phases of the Nankai Earthquake" would still indicate a high likelihood of a Nankai Trough Earthquake occurring during the 2030s.

Moreover, this periodic method of prediction tells us not only that this trough earthquake is likely to recur every 100 – 150 years, but also that there could be a longer cyclic pattern of 300 – 400 years (Ninna (M9) in 887; Shohei (M8.5) in 1361; Hoei (M8.6) in 1707) for a larger mega-earthquake, or indeed a connected chain of them. Following this alarming theory, the next connected mega-event would be due in the 21st century. It would seem that a Tokai Trough Earthquake, likely in chained occurrence, is due to precipitate a "Great West Japan Earthquake" and that there is no way of bypassing this fact.

The first blank question that calamity-struck residents will doubtless ask themselves after an event like that is the scientific one: "Why did this kind of ground liquefaction occur in my neighborhood?" In particular cases the victim may decide that it couldn't be helped or that one thing or another was to blame, but before that, the starting point for facing and coming to terms with what has happened has to lie in a scientific comprehension of the phenomenon itself and its occurrence. In Bulletin no. 5 ("Message"), soon after the Great East Japan Earthquake, I wrote the same thing and said that unless an answer can be offered in proper scientific / mechanical terms, residents of places like Urayasu (which suffered widespread liquefaction) will never be convinced. When the Great West Japan Earthquake comes – as come it will – we can be certain that there will be even more widespread instances of phenomena that have never been seen before. As one who seeks the starting place for disaster prevention in hardware, I trust that the activities of the ***GEOASIA*** Research Society will have contributed substantially to the improvement of disaster response technology through the precautions taken in civil engineering work. I also truly hope that the ***GEOASIA*** Research Society can play a large part in supplying the hapless victims of the next disaster with the demanded facts when they most stand in need of a "scientific answer."

The Research Society is still facing numerous burdens and challenges as regards both the wider dissemination of the ***GEOASIA*** ground analysis technology and the need to train up human resources through the ***GEOASIA*** Master program. I take the opportunity of this celebratory tenth "Message" to ask all of our members for their continued support.

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

Research Results in 2015

(1) Evaluation of the accuracy of an approximation used in a macro-element method in a numerical simulation of a ground treatment for the dissipation of excess pore water pressure

The accuracy of the approximation used in a new macro-element method was assessed in an application of the method to a dynamic problem. Based on an example of a ground treatment for the dissipation of excess pore water in an embankment, results from a 2-D surface strain analysis using the macro-element method were compared with others from a 3-D analysis using mesh divisions to obtain a strictly accurate representation of a drain. The new macro-element method was shown to give an adequate approximation of the controlling effect of the drain on the rise in excess pore water pressure, making it suitable for inclusion in a high-accuracy approximation of deformation and other such changes in embankments and their foundations.

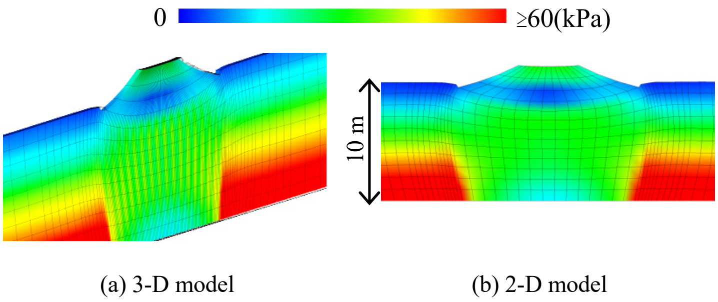


Figure 1. Excess pore water pressure distributions following an earthquake

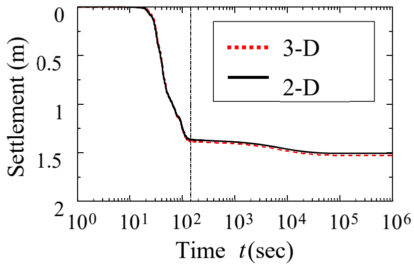


Figure 2. Comparison of surface settlement inthe central part of the ground treated

(2) Investigation of the mechanism of seepage failure in a river levee

Damage sustained by the levees of the Yabe River, northern Kyushu, during torrential rainfall in July 2012 led to levee failures resulting in a severe flooding impact without actual overflow. An analysis of this event was carried out in order to identify the seepage failure mechanism involved. Figure 3 shows the analysis section. In the half-section shown, a levee embankment is constructed on a foundation consisting of a low-permeability layer overlying a high-permeability one and water seepage is assumed to proceed from right to left while the overall water level remains constant. Figure 4 shows the shearing strain distributions and Figure 5 the mean effective stresses. The seepage of water into the boundary zone between the foundation layers is seen to set off a boiling effect that brings the mean effective stress in this area to near zero. In reaction to this, sliding begins to occur from around the foot of the levee embankment.

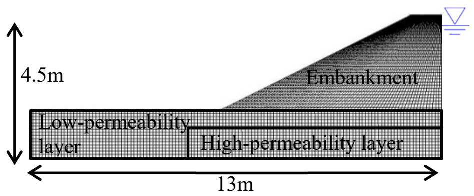


Figure 3. Analysis section

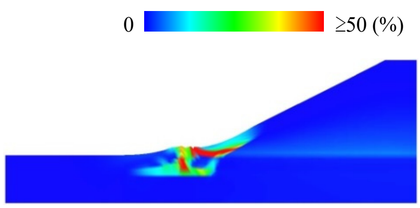


Figure 4. Shearing strain distributions

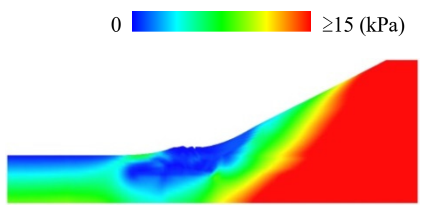


Figure 5. Mean effective stress distributions

(3) Investigation of the mechanism of increased liquefaction from earthquake aftershocks in cases where the main earthquake has caused saturation in a previously unsaturated ground layer

Following the Great East Japan Earthquake of 2011, there were reports from reclaimed coastal areas in Chiba Prefecture that liquefaction damage caused by the initial seismic shock increased considerably after a large aftershock occurring 29 minutes later. With this kind of report in mind, a simulation of a seismic shock was performed in the form of a three-phase (air-water-soil skeleton) coupled finite deformation analysis for the unsaturated top 2 m part of a 20 m thick sandy soil layer at the ground surface. Figures 6, 7, and 8 present the soil states in this top 2m part, initially, immediately after the main earthquake, and immediately after the aftershock. At the time of the main shock, there is a leap up in the underground water level accompanied by a fall in the mean skeleton stress in the high-saturation region. The occurrence of the aftershock then brings a further rise in the water level and a corresponding further fall in mean skeleton stress. In other words, it produces an increase in liquefaction. This kind of variation in the underground water level during and after an earthquake is a phenomenon that can be readily represented using an three-phase coupled finite deformation analysis built into the elastoplastic constitutive equation.

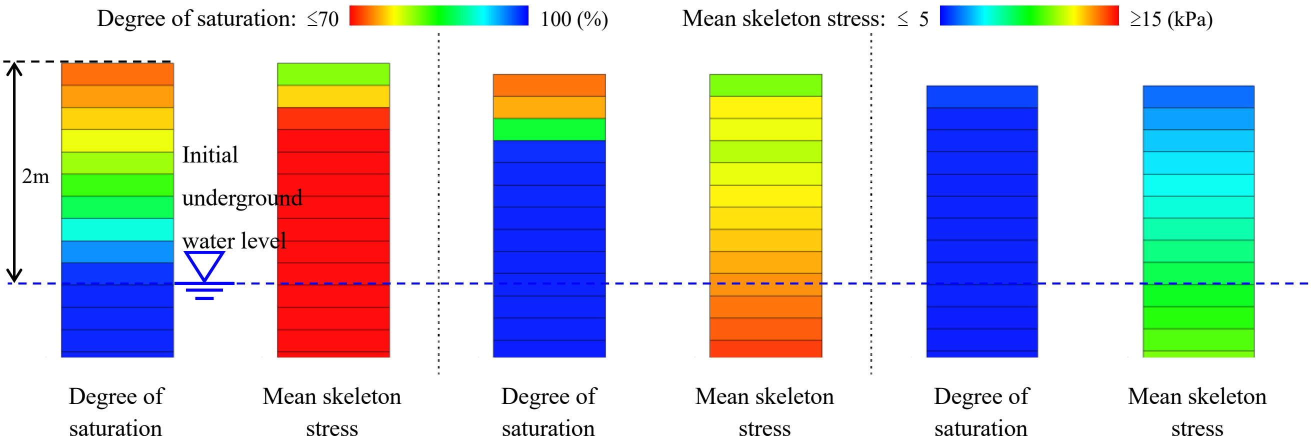


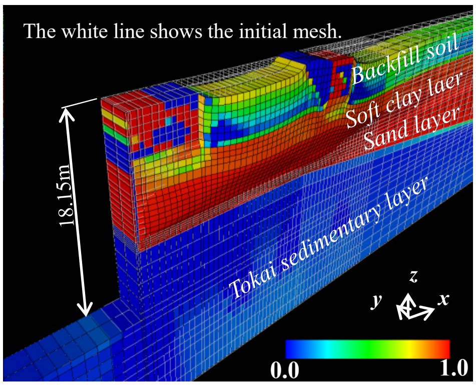
Figure 6. Initial soil state

Figure 7. Immediately after main earthquake

Figure 8. Immediately after aftershock

(4) 2-D/3-D verification of earthquake resistance for a coastal structure on a soft clay layer

An inspection for earthquake resistance was carried out for a coastal structure on an N-value zero foundation consisting of a layer of soft clay on a layer of sand, using a method that combined a 3-D stress analysis with a 2-D analysis of plane strain conditions. It was found that liquefaction was likely to occur in both the soft clay layer and the underlying sand, and the 2-D analysis revealed places in which the total plastic stress capacity of the sheet pile would be exceeded. However, the 3-D analysis showed that the stress would not surpass the yield bending point but would leave room for deformation in the y-axis direction (out of plane to the 2-D analysis surface). The problem could thus be addressed through a design correction.



*The amount of deformation is shown 4 times larger than scale.

Figure 9. Mean effective stress reduction ratio following an earthquake

Principal publications etc. in Academic Year 2015 (including the first half of AY 2016)

Academic papers:

【*Soils and Foundations*】①Simulation and evaluation of improvement effects by vertical drains/ vacuum consolidation on peat ground under embankment loading based on a macro-element method with water absorption and discharge functions, Vol. 55(5), pp. 1044-1057, 2015. ②Interpretation of the mechanical behavior of embankments having various compaction properties based on the soil skeleton structure, Vol. 55(5), pp. 1069-1085, 2015. ③Macro-element method with water absorption and discharge functions for vertical drains, Vol. 55(5), pp. 1113-1128, 2015. ④Study on the pore water pressure dissipation method as a liquefaction countermeasure using soil-water coupled finite deformation analysis equipped with a macro-element method, Vol. 55(5), pp. 1129-1138, 2015. ⑤Effects of air coupling on triaxial shearing behavior of unsaturated silty specimens under constant confining pressure and various drained and exhausted conditions, Vol. 55(6), pp. 1372-1387, 2015.

【*Soil Dynamics and Earthquake Engineering*】①Liquefaction countermeasures by shallow ground improvement for houses and their cost analysis, Soil Dynamics and Earthquake Engineering, 79, Part B, pp. 401-414, 2015. ②Analysis of the effect of groundwater level on the seismic behavior of an unsaturated embankment on clayey ground, Soil Dynamics and Earthquake Engineering, Vol. 85, pp. 217-230, 2016.

【*Journal of Japan Society of Civil Engineers, Ser. A2 (Applied Mechanics)*】①Effects of initial imperfection on the riedel shear bands in surface ground due to strike-slip fault, Vol. 18, I_463-I_474, 2015. ②Evaluation of mechanical behavior of a large river levee during seepage and during/after earthquake based on soil-water-air coupled finite deformation analysis, Vol. 18, I_621-I_632, 2015.

【*Journal of Japanese Geotechnical Society*】①Seismic response analysis of ground/geo-structures using geo-analysis integration code, Vol.63(10), Ser.No.693, pp.16-19, 2015. ②Application of seismic response analysis level2 earthquake for an existing river embankment, Vol.63(10), Ser.No.693, pp.28-31, 2015.

International conferences

【50th Indian Geotechnical Conference】1 papers. 【3rd AUN/SEED-Net Regional conference on natural disaster】2 papers. 【3rd International Workshops on Advances in Computational Mechanics】1 papers. 【The 12th World Congress on Computational Mechanics】1 papers. 【International Mini Symposium Chubu】4 papers.

Domestic conferences:

【70th Japan Society of Civil Engineers 2015Annual Meeting (Okayama, September 2015) 】7papers.
【19thSymposium on Applied Mechanics(Sapporo, May, 2016) 】1paper
【Japan Geoscience Union Meeting 2015 （Makuhari, May, 2016)】2paper
【21th Computational Engineering Conference （Niigata, June,2016)】3papers
【51h Japan National conference on Geotechnical Engineering (Okayama, September 2016) 】13 papers

Awards for Research using the *GEOASIA* Geotechnical Analysis Tool

【*Japanese Geotechnical Society 2015 Research Encouragement Award*】Takahiro Yoshikawa: Soil–water–air coupled finite deformation analysis based on a rate-type equation of motion incorporating the SYS Cam-clay model.
(https://www.jiban.or.jp/images/hyosyo/H27gakkaisho7-2.pdf)

Editorial Afterword

Looking back, the static deformation analyses that took up the first five issues of the *Bulletin* dropped into the background from Issue 6 on, when more dynamic problems such as changes in ground behavior before and after an earthquake began to account for all the activities reported. While this reflects the practicality of the ***GEOASIA*** software, it leaves one feeling a little sad for the basics. This year (2016), the ***GEOASIA*** Research Society celebrates its tenth birthday. From the bottom of our hearts we thank you for the precious gift of your contributions. We will continue to strive to live up to your expectations, and in that spirit we appeal for your ongoing support.

(Toshihiro Takaine)