GEOASIA Bulletin No.9

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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Message from the Society President

For the October 2015 special issue of the journal of the Japanese Geotechnical Society, focusing on the theme "Recent Trends in Seismic Response Analysis," several members of our research society under Professor Toshihiro Noda have authored an article illustrating the use of the ***GEOASIA*** analysis method. It is now nine years since the launching of the ***GEOASIA*** Research Society as an incorporated association pursuing activities for the dissemination of the ***GEOASIA*** geo-analysiscode, and at least as a name, ***GEOASIA*** is by now fairly well known in industrial, administrative and academic circles. That much is clear from the fact that an article like this was requested for the special issue in the first place. Naturally, the merits of ***GEOASIA*** were already sufficiently well recognized before. Awards from a number of academic societies, and certificates from the Minister of Education and Science, had cemented its reputation as "a systematic research for the clarification of both static and dynamic ground responses based on elastoplastic mechanics." All of these practical results and technical attestations supply welcome and valuable support when it comes to dissemination work. But when all is said and done, a pioneer developer is not often offered this sort of chance of an "official" platform from which to demonstrate the capabilities of a tool such as the ***GEOASIA*** geo-analysiscode. As the article in the October special issue is easy to follow and appropriate in its content matter, allow me the liberty of citing a few parts of it here.

"With previous geo-analysis codes, the choice of which code to use involved a prior decision of what was to happen in the ground. Codes were use-specific, so to speak, even for analyses of the same ground, there would be different codes and different input data for soil characteristics depending on the kind of engineering problem being tackled. (…) In the case of a ground made up of alternate layers of sand and clay, the ground consolidation behavior would be calculated by treating the sand as an elastic body and using a specific static consolidation code for the clay, whereas for behavior in the event of an earthquake the clay would need to be treated as elastic while using a specific liquefaction code for the sand." (…) "In order to create a new geomechanics that allows us to get away from this 'moment by moment' view of responses, our aim was first to give the soil constants and initial conditions for the ground and then, once this is achieved, to develop an analysis code capable of showing what will happen in a ground of this kind in response to such or such a pattern of external forces." To make all of this possible, "we developed ***GEOASIA***, an integral analysis code offering a unified framework to account for mechanical behaviors in all categories of soils ranging from sand to clay through all the myriad gradations between (ALL SOILS), under the proposed control of an elastoplastic constitutive equation (the SYS Cam-clay model) (…) based on a finite deformation theory applicable to all deformation and breakdown problems without distinction (ALL STATES), and, as a crowning advantage, it had to be usable in static and dynamic problems alike once allowance has been made for inertial force responses (ALL ROUND).” Most recently, “the code (is no longer) restricted in its scope of analysis to saturated soils (…) but its capabilities are being extended to deal with coupled three-phase (air-water-soil) analysis problems in which the distinction between unsaturated and saturated soil states falls away.”

As I already noted in my Message last year, this latest development of unsaturated soil analysis, along with the greater intricacy introduced into the elastoplastic constitutive equation by considerations such as hyperelasticity and the combined loading surface, are currently bringing about rapid gains in versatility for ***GEOASIA***. At the end of the article in the special issue, the following points are made about the precision of the ***GEOASIA*** analysis:

“In addition to the inevitable non-uniformity of the ground in any actual site, other practical problems include high degrees of uncertainty over what kind of seismic wave to input as an external force, and the further difficulty that many mechanical phenomena that are really 3-dimensional can only be represented in a stand-in way as 2-dimensional problems. Naturally, this places limits on accuracy. There is no point in getting too excited about small “quantitative” differences of a few tens of centimeters lost or gained. At present, the best we can aim for (…) is an analysis code of the kind that can supply sample concrete answers to “qualitative” problems and thus show, with respect to any assumed set of external force data, what series of events will occur in the ground affected and whether some design oversight might not need seeing to.” As for the present concern for dynamic problems involving external seismic forces and the like, the question to ask here is whether these are really being sampled appropriately.

In the same special issue last October, in addition to the article by Professor Noda and his collaborators there was another based on the case of an actual river embankment. It was by Professor Takeshi Kodaka and Society member Takahiro Yoshikawa (***GEOASIA*** Master) and involved the calculation of a seismic response in an unsaturated soil.

As is clear from the instances above, refinements are proceeding steadily in the development of the ***GEOASIA*** geo-analysis code. But this is also becoming ever more apparent through the expansion of the ***GEOASIA*** Master program. Of five very recent ***GEOASIA*** Master awards up to 2015, three went to students finishing graduate school courses: Toshiki Fukunaga in 2013, and then Kenta Kato and Takahiko Goto in 2014. All three of them made distinguished contributions to the refinement of the ***GEOASIA*** code either in developing new applications, e.g., for mutual interactions within combined ground and structure systems at the time of an earthquake occurrence, or for the behavior of unsaturated soils, or, more methodologically, in the enhanced “visibilization” of dynamic nonlinear problems using progressive linear approximations. Previously, there seemed to be a sense of the ***GEOASIA*** Master program being confined to doctorate candidates, but seeing it beginning to spread like this outside of those earlier bounds is a gratifying sign of the greater diffusion of the ***GEOASIA*** geo-analysis code. So far, the growth has not spread outside of the research laboratories of Nagoya University, but what we are now seeing for ***GEOASIA*** may be the birth stages of a wider advance into educational technology, as a new approach to geomechanics. Last but not least, March 2015 saw the appointment of Toshihiro Takaine, our first ever ***GEOASIA*** Master, as (full-time) assistant administrator of the Research Society office. I am sure that this, too, will be of great significance for the further expansion of ***GEOASIA*.** Hopefully, a result, ***GEOASIA*** will seem closer at hand, and more accessible, to many Society members.

Next year, 2016, will mark the tenth anniversary of the Society’s foundation. Let us concentrate our efforts in the remaining year up until then so as to be able to report to our members the realization of some of our longstanding ambitions such as the preparation for press of a ***GEOASIA*** textbook, the release and sale of a diffusion edition of the ***GEOASIA*** geoanalysis code, the opening of a Tokyo office for the ***GEOASIA*** Research Society, to name just a few.

A closing word: Readers will probably have heard of the sad loss of Professor Minoru Matsuo on May 9, 2015. In common with many of the academic staff belonging to the Society, I remember him as a cherished teacher. The

July issue of the Japanese Geotechnical Society journal included an obituary article. I hope that members will read it and savor the pleasure of a trip back to old times.

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

Research Results in 2014

(1) An example for the elastoplastic modeling of materials other than the ground

An investigation was conducted into the protective effect of a method consisting in driving an array of prevention piles into the ground at fixed intervals on the landward side of an existing coastal protection wall to guard against lateral flow in the soil behind. Assuming the prevention piles to be made of steel, the piles were modelled as elastoplastic materials which are controlled by subloading surface rule under von-Mises yield criterion. The yielding of an elastoplastic embedded pile was found to lead to a greater displacement than that of an elastic embedded pile, and the amount of settlement at the ground surface, calculated in comparison with that which would occur if no restraining measures were taken, was found to decrease on the landward side of the pile and increase on the seaward side.

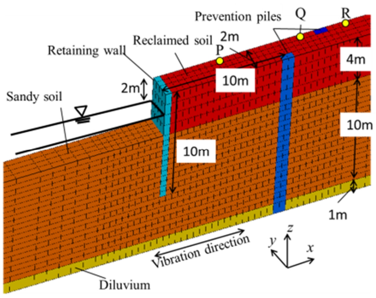


Figure 1. FEM mesh used in analysis

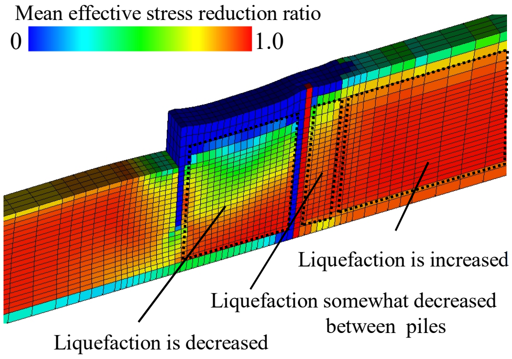


Figure2. Effect of prevention piles

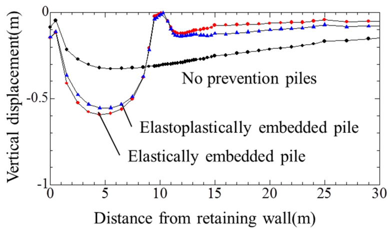


Figure3. Surface settlement distributions

(2) A simulation of irregular seismic wave generation accompanying the collapse of a dip-slip fault

An attempt was made to generate a computer model for an earth movement through the use of induced collapses in normal or reverse faults. By introducing random material heterogeneities into the ground, it was possible to generate irregular seismic waves. It was found that if the loading is carried on further after the collapse of the fault, the collapse process itself will begin to move into a recursion sequence, with a certain interval of time left between each two recursion cycles.

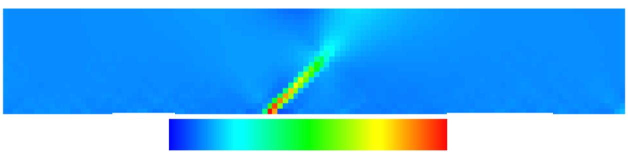


Figure 4. Shear strain distributions in the case of a reverse fault (12449.8 sec after the start of similation)

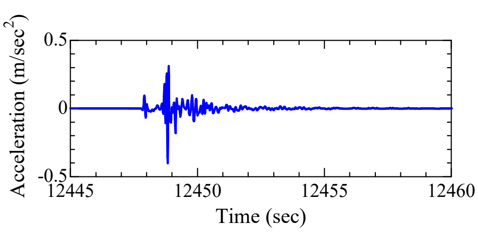
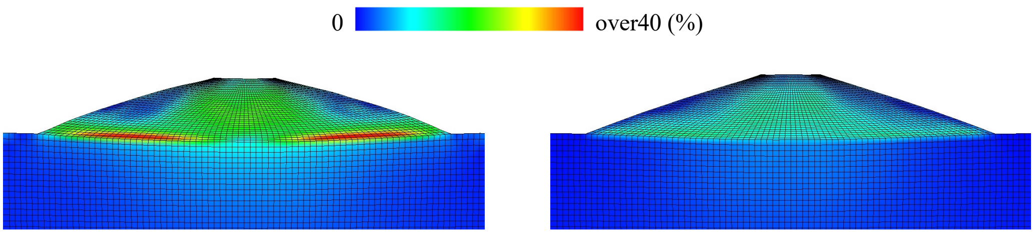


Figure 5. Horizontal acceleration at the ground surfacein the case of a thrust earthquake

(3) Soil-water-air coupled finite deformation analysis of the seismic behavior of an unsaturated embankment on a clayey ground, with particular reference to the ground water level

An analysis was performed of the behaviors of an unsaturated embankment on a clayey ground at the time of its construction and then during and after an earthquake, paying particular attention to the ground water level. Result for a case in which the ground water level was high showed higher degree of saturation in the embankment and lower soil skeleton stress, compared with the other in which the ground water level was low. The earthquakes occurring in the condition thus resulted in more deformation, a finding which agrees in tendency with damage observed at the time of the Great Eastern Japan Earthquake (Figure 6). In the aftermath of the earthquake, it was further found that phreatic line formed inside embankment in high ground water location, but not in low ground water location, although here, too, there have been some rise in the water level.

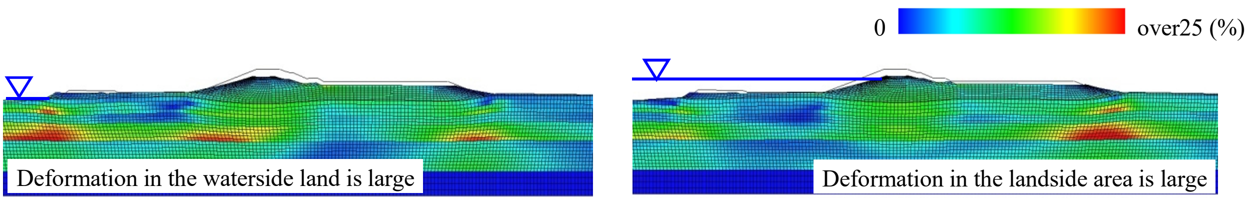


(a) Ground water level=GL-0m (b) Ground water level=GL-2m

Figure 6. Shear strain distributions immediately following an earthquake
(The higher the ground water level, the greater the deformation)

(4) Assessment of seepage and seismic response behavior in a large river levee, taking account of the river water level

An assessment was performed forseepage and seismic response behavior in an existing large river levee on a ground composed of alternating layers of sandy and clayey soils. An analysis was made for a combination of seepage and earthquake responses (Figure 7), from which it was found that the higher the river water level the greater the deformation would be in the landside area. A verification analysis was also performed for the assumed case of a sandy soil virtually gravelly in its coefficient of permeability, from which it could be seen that after a lapse of around 8 hours following the rise in the water level, piping / boiling failure may occur.

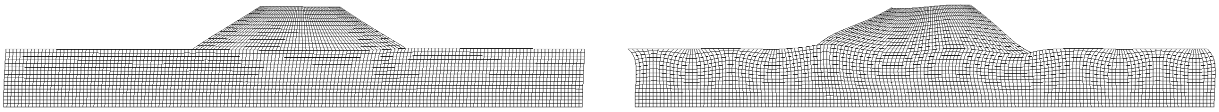


(a) A case where the river water level is low (b) A case where the river water level is high

Figure 7. Shear strain distributions immediately following an earthquake
(The higher the river water level, the greater the deformation in the landside area.)

(5) Use of an irritation index to assess the earthquake susceptibility of an earth structure-ground system in its natural vibration frequency mode

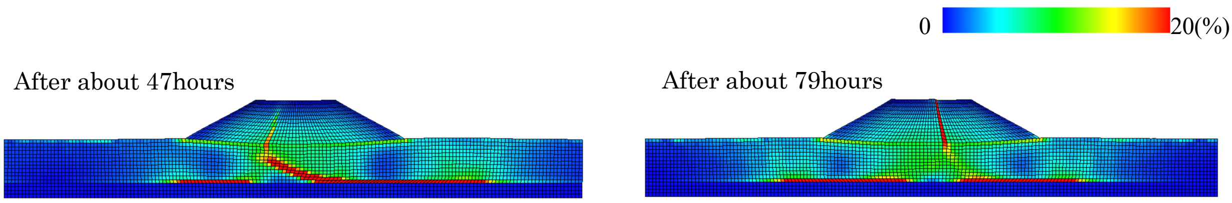
A mehod was developed for obtaining natural vibration characteristics of ground and soil structures based on the coupled finite deformation analysis in discrete linear approximation scheme, under the constraint condition of a viscosity boundary. In order to reduce the potentially vast number of natural vibration modes obtainable from a natural data analysis down to the predominant modes that are of prime concern for the system's seismic response, a (local) irritation coefficient was additionally proposed to evaluate earthquake susceptibility for each mode. Figure 8 shows evaluation results obtained. The primary frequency mode is conducive to considerable shaking in the ground, while the secondary one leads to strong tremors in the embankment. Figure 9 shows the seismic responses analytically calculated for these two main frequency modes. The seismic waves included in the two diagrams were obtained in each case by combining the dominant frequency with the two distinct frequencies of the natural vibration modes. For the combination in the primary vibration mode the shear slip surface was found to develop within the ground, for that in the secondary mode, within the embankment.



(a) Primary: ground mode (natural vibration frequency 0.698 Hz)

(b) Secondary: embankment mode (natural vibration frequency 1.935 Hz)

Figure 8. Values of earthquake susceptibility for the two natural frequency modes



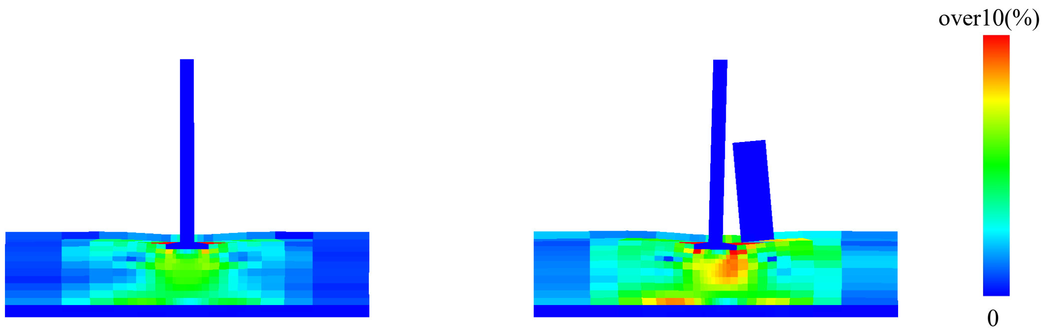
(a) Results for the wave resulting from dominant vibration frequency 0.700 Hz

(b) Results for the wave resulting from dominant vibration frequency 1.933 Hz

Figure 9. Shear strain distributions upon the assignment of the frequencies for the two natural vibration modes

(6) Assessment of the earthquake resistance of an interacting system comprising a ground and a smokestack structure

An evaluation was performed for the seismic behavior of a high-standing smokestack structure built on a soft ground. The two principal findings were: ① The earthquake resistance of this interacting system was determined not only by the softness of the ground and the intensity of the earth movement, but also significantly in relation to 1) the natural vibration period of the structure, 2) the natural vibration period of the ground, and 3) the dominant period of the assumed input seismic motion. ② The smokestack structure was in danger of leaning over as an induced effect of ground settlement occurring around an adjacent structure.



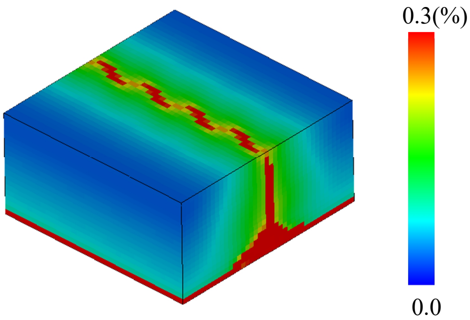
(a) The case of the smokestack considered alone

(b) The case taking account of an adjoining structure

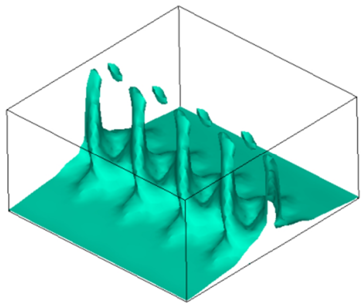
Figure 10. Shear strain distributions 300 sec. after an earthquake

(7) Accompanying faults in a ground adjacent to a strike-slip fault

When seismic activity occurs in a laterally displaced fault, it is well known that it may be accompanied by subsidiary features such as "Riedel shears," zones of shear faults along the main surface fault line or "flower structures" branching up from deep subterranean levels to the ground surface. Figure 11 shows an analytically created example that attempts to replicate the development process of these accompanying faults in a case where lateral slippage is provoked in the lower part of a modeled ground representing the upper part of a geological fault. From the analysis it is clear, first, that Riedel shears are generated as accompanying features of an elastoplastic swelling in the ground materials, and, second, that the growth of such features is due to a great extent to the given initial material imperfections that exist in the ground.



(a) Riedel shear zone (shear strain surface)



(b) Flower structures（Contour surface (ε_s=0.5%) of shear strain）

Figure 11. Flower structures due to initial imperfections in the ground material and the accompanying Riedel shear zone

Principal publications etc. in Academic Year 2014 (including the first half of AY 2015)

Academic papers:

【Soils and Foundations】①Soil-water-air coupled finite deformation analysis based on a rate-type equation of motion incorporating the SYS Cam-clay model, **55**(1), pp.45-62, 2015. ②Simulation of large-scale deformation of ultra-soft peaty ground under test embankment loading and investigation of countermeasures effective against residual settlement and failure, **55**(2), pp. 343-358, 2015.

【*Japanese Geotechnical Journal*】Mitigation of liquefaction-induced damage to residential houses by surface ground improvement and its cost evaluation, **9**(4), pp.533-553, 2014.

Domestic conferences:

【69th Japan Society of Civil Engineers 2014Annual Meeting (Osaka, September 2014) 】11papers.
【18thSymposium on Applied Mechanics(Kanazawa, may, 2015) 】1paper
【50h Japan National conference on Geotechnical Engineering (Sapporo, July 2015) 】18 papers
【20th Computational Engineering Conference（Tsukuba, June,2015)】1papers
【Japan Geoscience Union Meeting 2014（Makuhari, May, 2015)】1paper

Editorial Afterword

The research activity reports in this bulletin issue include one case of a material other than soil being admitted into an elastoplastic constitutive equation, two cases having to do with the generation of geological faults, two involving unsaturated soil embankments, and two concerned with earthquake movements in interactive systems. These 7 innovatory activity reports are obviously all fine examples of what has been said in the Message from the Society President above about the further refinement of ***GEOASIA***. But at the same time, we are no less concerned with important basics such as the publication of a teaching text, and the public release and increased diffusion of the ***GEOASIA*** program. In the year to come, we once again appeal to all of our members for their continued support for research activities.