GEOASIA Bulletin No.12

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

The West Japan Heavy Rain Disaster at the beginning of July (2018) came as quite a shock. In response, I am going to cut back the contents I meant to talk about to a few words at the close and begin by talking instead about this rain disaster.

Developing out of Typhoon No. 7 ("Typhoon Prapiroon") at the end of June, a "linear precipitation zone" of a type not previously familiar passed over Western Japan from Saga Prefecture on July 7 to Gifu Prefecture on July 9 causing widespread heavy rain damage. In addition to the wide extent of the damage, the sheer amount of continuous heavy rain from July 6 to July 8 (three-day totals in excess of 500 mm, with extremes of over 1800 mm in parts of Ehime and Kochi) set new records virtually everywhere.

More than 220 human lives were lost, many of them victims of rockslides in decomposed granite mountainside zones. But in addition, it is worth remembering that these deaths also included: ① more than 50 from river water floods in the Mabi district of Kurashiki where the Oda and several other tributaries of the Takahashi River broke their embankments to create conditions which it is hard to know whether to describe better as outflow (river flooding) or inflow (overland flooding); ② at least 23 following the overflow and then failure of a debris flow containment dam in Hiroshima Prefecture; ③ 5 resulting from an operating "mistake" at a dam in Ehime Prefecture.

Let me add that the Ministry of Land and Transport has since posted a short 15-minute video on YouTube showing the results of a detailed simulation of the river flooding (outflow) that would result from three days of continuous rain exceeding 500mm in total in the Chichibu area of Saitama around the upper reaches of the Arakawa River that flows into Tokyo.

There is no reason to suppose that conditions with the same novel characteristics as the West Japan Heavy Rain Disaster (widespread continuous rainfall in vast amounts) could not strike Tokyo, Osaka, Nagoya, or other large conurbations. We often hear lately that the sewers, subsurface dams, underground transport networks and so on in large cities are now securely safeguarded against inflow-type overland flooding. But it is much rarer to hear that much progress has been made in ground improvements, super-embankments and similar safeguards against outflow-type river flooding.

Massive rainfall is not our only worry. Tokyo, and the other large conurbations, are perfect targets for direct epicentral earthquake strikes or offshore trough earthquakes. Long-period / long-duration seismic movements striking sedimentary basins can cause huge ground disturbances in soft clay areas that were supposed to be "proof" against earthquakes. "The embankments on soft clay grounds in large conurbations are at risk." This is an issue that has shown up time and again in calculations performed with ***GEOASIA*** software. In the three main conurbations

named above, there are a total of more than 4 million people living in extensive zones zero meters above sea level. What would become of them if an earthquake were to destroy a seawall embankment and let in the ocean? The fatality numbers that come to mind run far in excess of 200. It makes one quite gloomy to think how frail and exposed our big cities are against external forces of nature such as earthquakes or extreme rainfall. Looking at the images of the heavy rain disaster, the two thoughts that came home forcefully to me were, first: "The basic key to disaster prevention is in hardware," and then second: "***GEOASIA*** has so much to offer to the technologies for ground improvement and embankment reinforcement; if only we could make this even more widely known."

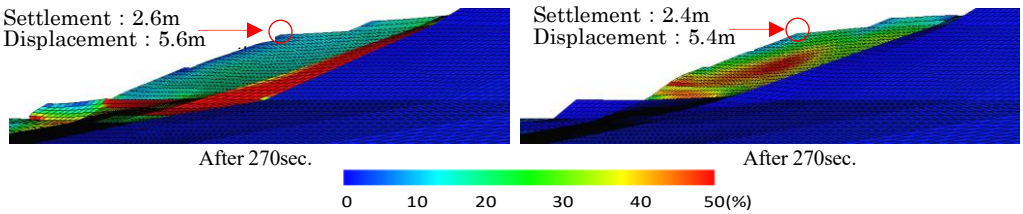
Work pursued in the ***GEOASIA*** Research Society in recent years has been concentrated especially on the theoretical side, including notably: ① a more deeply penetrating version of the combined loading model for the finer description of dynamic characteristics in sandy soils; ② enhancement of the 3-phase soil skeleton -water- air analysis; and further, ③ elaboration of the theory for a Full Formulation description of a multi-phase mixture, with means for overcoming impediments to computation. While excellent progress has been made in each of these several projects, the steady improvements thus achieved in geo-mechanical theory and the accuracy of calculations also gives rise to situations in which particular research objectives become hard to reconcile with the more ongoing aim of "spreading the use of ***GEOASIA***". In the coming year, we hope to be able to report a more satisfactory solution to this conflict.

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

Research Results in 2017

(1) Analysis of the seismic response of an embankment built on an inclined ground having a layer of loose (low N value) sand as its surface layer

An embankment built on a layer of sand having a low N value offers a large confining pressure, but with an increased risk of earthquake deformation due to shearing. The present research began from a seismic response analysis of an embankment built on this type of low N value sand foundation and assessed the resulting ground deformation. While the change in the state of the sand layer did not amount to liquefaction, a definite decrease was found in mean effective stress, leading to large deformations (Case 1). When a further analysis was performed on the assumption of higher degrees of structuring and over-consolidation in the sand layer, the deformations in the sand layer itself were smaller while the deformations in the embankment increased (Case 2). Consequently, there was no difference in the amount of overall displacement. Figure 1 here is for the left side of the embankment.



(a) Case1 (b) Case2

Figure 1. Share strain distributions

(2) Analysis relating to a method of liquefaction and lateral flow restraint for a quay

This research investigated and discussed the effects of a method for restraining liquefaction and lateral flow in the ground behind a quay making use sheet piles driven in behind the rear of the wall as shown in Figure 2. As appears in Figure 3, for the state just following the end of an earthquake, a liquefaction restraining effect behind the wall can be confirmed from the distribution of the falls in the mean effective ground stress. Further, as indicated by the contours in Figure 4, in place of the extensive horizontal ground displacement toward the sea that would

accompany the deformations in the piling behind the wall assuming no countermeasures were taken, in treated grounds this lateral displacement is inhibited. From this, it could be confirmed that the method investigated had an effect as a measure of restraint against liquefaction and lateral flow.

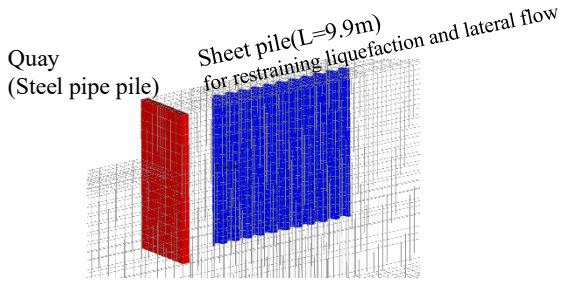


Figure 2. FEM mesh

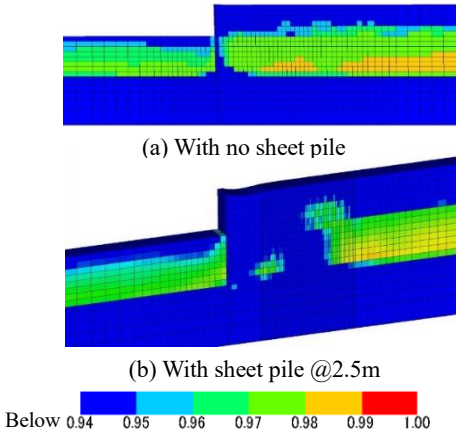
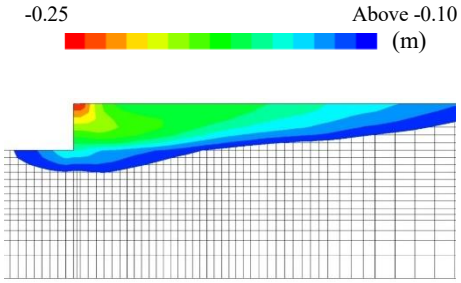
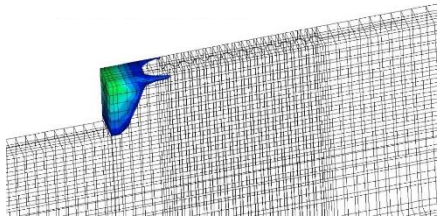


Figure 3. Mean effective reduction ratio distibutions immediately after an earthquake



(a)With no sheet pile



(b) With sheet pile @2.5m

＊Display a lateral displacement of 0.1m or more on the sea side (left side of the figure)

Figure 4. Lateral displacement at the end of post-seismic consolidation

(3) Comparison of two and three dimensional analyses of seismic response and post-seismic behaviours in the foundation ground of a spherical gas holder

For a spherical gas holder supported in a soft ground on pile foundations, two dimensional plane strain conditions were calculated and a three dimensional analysis also performed for a case in which the piles were assumed to have lost their supporting function at the time of an earthquake. From a comparison of the results, it was found that the three dimensional analysis of the behaviours of the gas holder and its foundations was generally well matched by the results of the two dimensional plane strain analysis, showing that, subject to certain conditions, the two dimensional plain strain analysis can be usefully adopted as an evaluation basis for earthquake resistance.

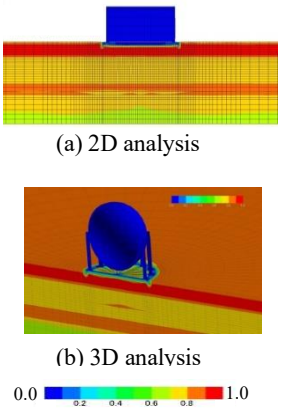


Figure 5.Mean effective reduction ratio distibutions immediately after an earthquake

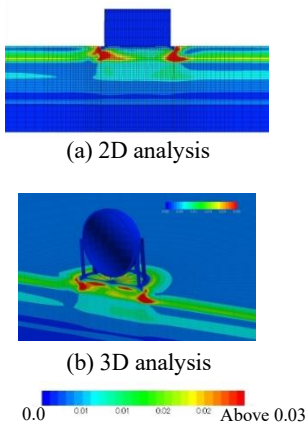


Figure 6. Shear strain distributions at the end of post-seismic consolidation

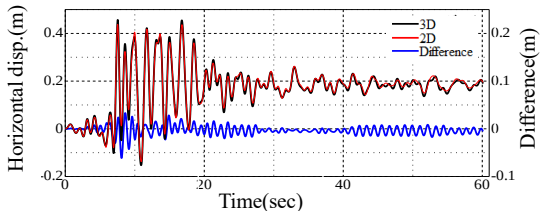


Figure 7. Horizontal displacement time history of upper end of column during earthquake

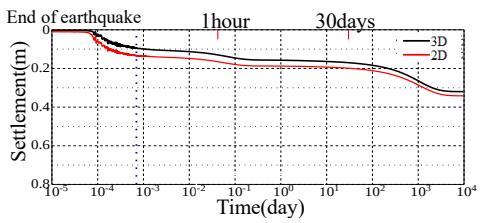
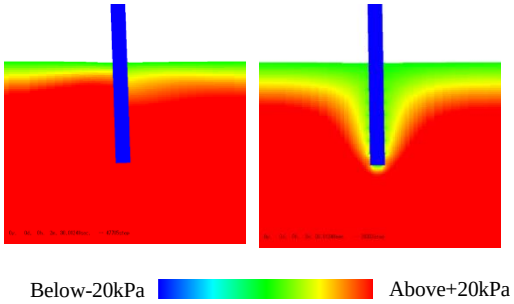


Figure 8. settlement time history of the foundations

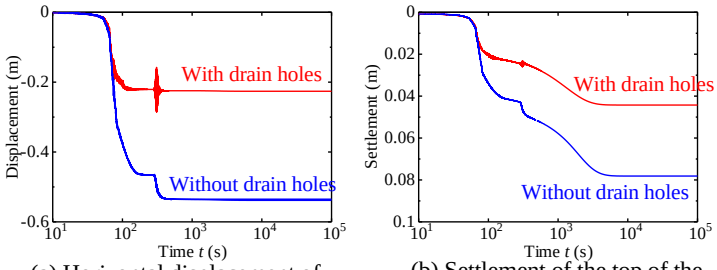
(4) Numerical analysis to verify the viability of a method of drainage for electric utility poles

Trials are underway to control the subsidence or inclination of electric utility poles in grounds subject to liquefaction by fitting them with drain holes. An earthquake response analysis was undertaken to verify the effect of this measure, and it was clear from the results that while the enhanced drainage allowed no falling off in the force gripping the poles into their foundations, and hence little displacement, it also made it more difficult for excess pore water to accumulate in the soil during the earthquake and in this way contributed to a reduction in post-seismic drainage subsidence as well.



(a) Without drain holes (b)With drain holes

Figure 9. Excess pore water pressure distributions after the main shock



(a) Horizontal displacement of the top of the electric pole (b) Settlement of the top of the electric pole

Figure 10. Displacement behavior after and during earthquake

(5) Effects of ground layer irregularities on surface layer ground damage during an earthquake

In this research, a multidimensional earthquake response analysis was carried out taking account of ground layer irregularities, leading on to an enquiry into the formation of surface waves and the ways in which complex interferences between surface and body waves affect surface layer ground damage. The results show that this notion of a multidimensional effect that can be summed up in the terms “formation” and “propagation” of a surface wave and poses a requirement for damage predictions accurate and adequate enough to match actual needs, is a matter worth thinking about. This also suggests that there is a need and a use for multidimensional analyses that bring in surface layer irregularities.

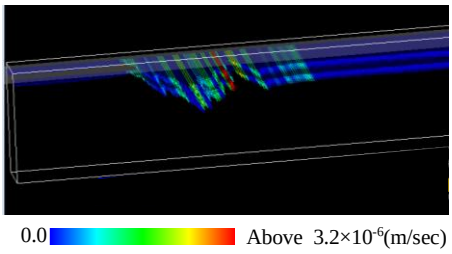


Figure 11. Generation of Love waves at the inclined bedrock

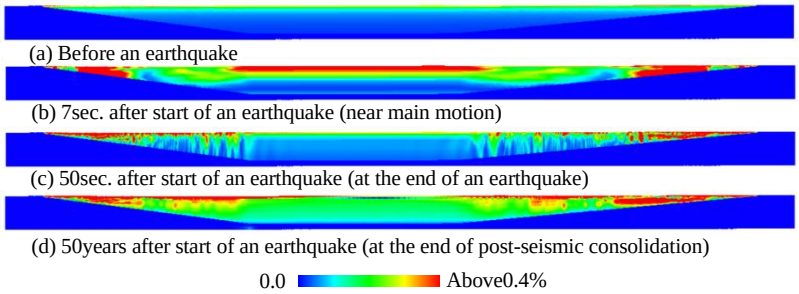


Figure 12. Localization and expansion of damage in sedimentary basin(Shear strain distributions)

(6) Simulation of a liquefaction experiment making use of combined loading elasto-plastic constitutive model

In previous research we have already introduced the combined-loading elasto-plastic constitutive model that brings together the capacities of the SYS Cam-clay model and the non-associated Drucker Prager model by openly handling combined loading conditions. We have further managed to enhance the power of the constitutive equation through the introduction of induced isotropy. The research presented here is the simulation of liquefaction experiments

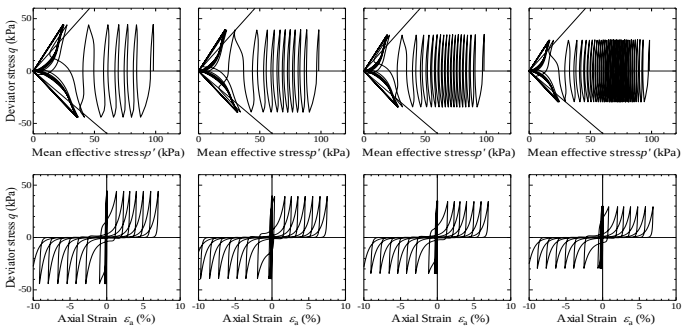


Figure 13. Simulation of liquefaction experiment of Toyoura sand with 76% relative density

using Toyoura sand (Figure 13). These results demonstrate the high descriptive response capability of the equation in its current state.

(7) Estimation of the bedrock elevation wave at the Aratozawa Dam at the time of the 2008 Iwate-Miyagi Nairiku Earthquake

In the Iwate-Miyagi Nairiku Earthquake of 2008, a particularly strong ground tremor reading was obtained at the Aratozawa Dam (① maximum acceleration at the dam foundation exceeded 1,000 Gal, ② further up, in the middle part of the core, and higher again at the crest of the dam, acceleration was limited to about 500 Gal). Characteristics of this sort had previously never been observed at a Japanese rock-fill dam. With the use of the ***GEOASIA***, it was possible not only to reproduce figures similar to the ones observed, but also to show that the principal cause for such distinctive results lay in the deterioration history of the ground materials. Following this, an analysis was run by subjecting this problem to a bedrock elevation estimation method using viscous boundary conditions originally proposed within this Research Society and Nagoya university geomechanics group. The incident wave for the time and site in question could then be estimated, but with the result that the acceleration figure came to around half of what had been actually observed and recorded Figure 14. In recent years, we have seen continuous upward revisions of seismic design forces, and this is one further result that is likely to raise questions as to the aptness of seismic design standards.

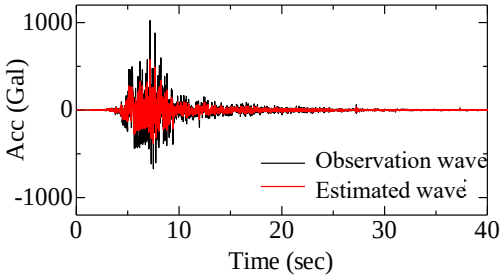


Figure 14.Observed wave on the dam foundation and estimated upward wave

(8) Generative simulation of Riedel shear zones, depending on the presence of "jogs"

When displacement occurs in a laterally slipping fault buried deep down beneath covering layers of sedimentary rock, echelons of cracks known as Riedel shears will appear on the top surface like geese flying in formation. If the model illustrated in Figure 15 is grasped at the bottom end to enclose the winding fault area and then given a local "jog" of displacement, an extensive Riedel shear zone will form, as shown in Figure 16 (a), with more local, and smaller Riedel zones enclosed within a reducing series of fractals. Further, if the size for the model is changed as in Figures 16 (b) and (c), the larger-scale P-shear can be brought into view, along with other lower- or higher-angles of the shearing pattern. In addition, as in Figure 17, petal-like slip surfaces ("flower structures") also occur, and again reproduce themselves into complex combinations.

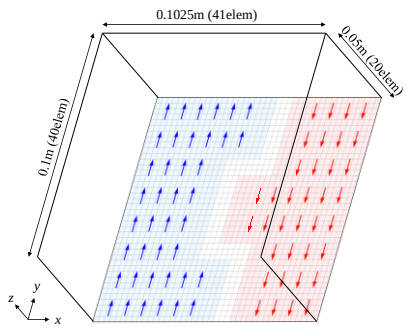


Figure 15. FE mesh with bent fault zone

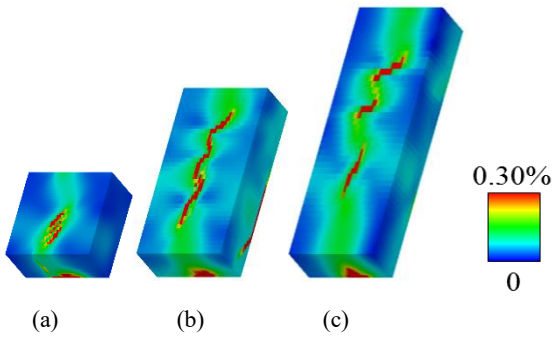


Figure 16. Shear strain distributions

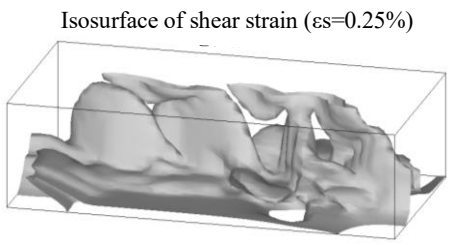


Figure 17. Generation of composite flower structure

Principal publications etc. in Academic Year 2017 (including the first half of AY 2018)

Academic papers:

【Soils and Foundations】 Verification of a macro-element method in numerical simulation of the pore water pressure dissipation method -a case study on liquefaction countermeasure with vertical drains under embankment, Soils and Foundations, Vol.57(3), 2017.

【SEAGS】 Soil-water coupled of pore water pressure dissipation in performance design - Examinations of effectiveness in reclaimed ground., Geotechnical Engineering Journal of the SEAGS & AGSSEA, Vol.48, No.4, pp.19-31, 2017.

【Journal of Applied Mechanics, Japan Society of Civil Engineers (A2)】 ①Soil-water coupled finite deformation analyses on subgrade reaction of pile which were embedded into naturally deposited foundation, Vol.73, No.2, p. I_535-I_544, 2017.1. ②Seismic assessment of Nagoya Port Island changing landfill height against Nankai Trough earthquake, Vol.73, No.2, p.I_233-I_244, 2017.

【Canadian Geotechnical Journal】 ①Seismic assessment of sheet pile reinforcement effect on river embankments constructed on a soft foundation ground including soft estuarine clay, Canadian Geotechnical Journal, Vol. 54, No. 10, pp. 1375-1396, 2017.3. ②Deformation/failure mechanism of saturated fill slopes due to resonance phenomena based on 1G shaking-table tests, Canadian Geotechnical Journal, Vol. 54, No. 10, pp. 1375-1396, 2018.3.

International conferences:

【19th International. Conference on Soil Mechanics and Geotechnical Engineering (Seoul)】
①Expansion of SYS Cam-clay model for simulation of mechanical behavior of cement-treated soils. ② Verification of macro-element method for vertical drains in dynamic problem. ③A consideration of the failure mechanism of river levees due to water seepage based on model tests and soil-water-air coupled finite deformation analysis. ④A full formulation-based soil-water coupled finite deformation analysis on undrained compression tests on highly permeable soil specimen. ⑤1G shaking table tests on saturated fill slope focusing on resonance phenomena. ⑥Numerical extraction of Rayleigh waves and assessment of their influence on liquefaction damage.

* *Starting from this 2018 issue, we are changing our annual span of coverage from the Japan business year to the Japan Academic Societies year. As a result, there is a small overlap of reporting this time with one or two items previously included in issue 11 of the Bulletin.*

Editorial Afterword

The research activities reported above include four achieved with the aid of three-dimensional analysis. The computational time this requires is still considerable, but it seems fair to say all the same that this is coming to be seen as routine. As noted in the President's Message, newest developments such as the introduction of an enhanced constitutive model, the current challenge of three-dimensional soil skeleton -water- air analysis, and more generally the theoretical goal of Full Formulation that positions ***GEOASIA*** as a general tool of ground analysis, are outward signs of a new threshold coming to be crossed. Next year (2019) marks the tenth anniversary of the registration of the ***GEOASIA*** Research Society as a general incorporated institution. As such, we continue to rely on the attentive goodwill of our many supporters. I therefore close with a renewed appeal for their unstinting assistance.

(Toshihiro Takaine)