

# **GEOASIA Bulletin No.14**

**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

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## **Message from the Society President**

I want to begin this time with some rather cheering news about river levee engineering. Two months after the 2019 GEOASIA General Meeting, on October 12 and 13 last year, Typhoon 19 (Typhoon Hagibis) caused extensive flooding, notably along the Chikuma River in Nagano and the Abukuma River in Fukushima. In Japan as a whole, levee failures occurred in 142 places, with river overflow as the primary cause in 86% of these. The resulting damage was horrific, and included the flooding of some 35,000 hectares of land. In the aftermath of the Kinugawa River levee failures of 2015, there had already been some talk of the need for “structural measures of crisis management type,” but in the end, all that was painfully apparent once more was the inadequacy of the solutions offered.



Accordingly, in February 2020, the Water and Disaster Management Bureau in the Ministry of Land and Transport decided to launch a discussion of technical issues concerning river levees, taking account of the damage from Typhoon 19. After three rounds of deliberation, the final report was published in August. Hearings were also conducted among civil engineers in the private sector to obtain a broad spread of views on developments in soil reinforcement methods from outside the discussion group. I cannot pass on here without pausing to recall the esteem I felt for civil engineers such as the ones from the Japanese Technical Association for Steel Pipe Piles and Steel Sheet Piles who saw this as their awaited chance to present already available Research and Development findings. They rose actively to the occasion.

In the report, there is no explicit talk of “abandoning the earth embankment principle,” but there is a clear recognition that merely conventional “structural measures of crisis management type” of paved crowns and rear toe reinforcements have their limits. What is needed is a more “tenaciously effective” range of design, involving reinforcement techniques that can be classed roughly into three types of ① surface cladding ② section widening, and ③ limited local autonomy (the adding of steel pipes, steel sheets or soil-cement walls, etc.). The intention is to promote R & D in these several sorts of levee reinforcement methods, while also extending collaboration between public research institutes, private bodies and universities. According to a senior colleague who ventured out in the Coronavirus pandemic to inspect reconstruction site conditions in the Hoyasu district alongside the Chikuma River, the actions now being taken went beyond the “structural measures of crisis management type” of the past. The new levee was being built with a continuous covering of blocks along its rear wall to withstand overflow. Even in some cases where “non-structural” measures are enough to save lives, the loss of a home or of possessions may be enough to make some people lose the will to live. We see this happening year after year. I am repeating from last year, but the crux of disaster prevention lies in hard response measures. Civil engineers stand

in the forefront of the effort to see that they are taken.

No sooner do we reach this new departure point, but we find our attention being diverted again by another dire emergency placing a different question mark on the social responsibility of civil engineers. In the morning edition of the Tokyo Shinbun Newspaper of June 7, vying for attention with Tokyo virus alert," another article turned up with the headlines: "2027 Linear Opening heading for postponement" and "Talks in Shizuoka: Governor to withhold construction approval." Due to fears in Shizuoka that changes in the subsurface geology of the Southern Alps could provoke water catchment loss in the Oi River system, a likely delay was reported in the planned 2027 opening of the first section of the "Linear Central Shinkansen" between Shinagawa (Tokyo) and Nagoya. The gist of articles in the Asahi and other leading newspapers was the same: "Shizuoka to blame for Linear delay."

Between now and 2027, there are only 7 years to go. Even after completing the tunnel, there will be a spate of other tasks waiting. First, the installation of the driving equipment. This corresponds to the rails and concrete slabs of a conventional track, except that for a maglev it involves the building of four shielded vertical walls, made of concrete and fitted with magnetic coils to supply alternating forward impulsions from both outer sides of the advancing train. After that, more time is needed for driver training, and for evacuation drills in case of an accident. Assuming that all of this can be completed in two to three years, that allows just four or five years for boring the tunnels. For the 10.7 km Hida Tunnel, a boring time initially estimated at 5 or 6 years finally ran up to more than a decade. While the leading dailies are entitled to tune up for their welcoming of the Linear Shinkansen, it is another matter whether their thinking ought to be quite so set on the 2027 completion target being met.

Leaving aside questions of keeping to schedule, is this tunneling project feasible in the first place? Granting that the 15 km section under the main ridge of the Ina Mountains goes through quartz and should be easy drilling, the 25 km Akaishi Mountains stretch under the South Alps will be a different story. Geologically, the Akaishi Mountains belong to the Outer Zone of Southwestern Japan and make up part of the Shimanto Belt accretionary wedge, mainly formed between around 100 and 20 million years ago. Within this accretionary wedge, the Akaishi Mountains are known as strata of extremely heterogeneous material known as *mélange*, highly prone to structural shearing, in which rock fragments of every variety and scale, some pelagic, others terrestrial in origin, occur mixed together in a mud base. In addition to this, other vast changes 20 to 15 million years ago (enlargement of the Japan Sea, formation and curving of the Japanese islands, collisions with the Izu arc of islands) led to the creation of the north-south Itoigawa-Shizuoka Tectonic Line, which was then drastically transformed by being pressed on both sides by the east-west Median Tectonic Line until its initial pattern became overprinted with more complex internal lines. This explains how the Akaishi Mountains came to be the most intensely transformed part of the Shimanto Belt accretionary wedge. At the risk of repetition, I wish to reiterate that a mountain massif is quite different from a continuous mass of mountain. In an extreme case, the massif may turn out to be a *mélange* mountain mass, supported deep underground by accumulated water held in under enormous pressure. Finally, the Akaishi Mountains are a rising range. This has clearly been so for the past million years, but even in the past century, areas around the main ridges have been showing one of the world's fastest rates of altitude gain: up to 4 mm annually. Even today, the Akaishi Mountains are a place of vigorous change in the earth's crust. The tunnels, for the most part, run deep underground. The maximum distance below the surface is 1400 m. It is a basic practice in tunnel boring that no further drilling advance be made until the water pressure at the work face has been brought down sufficiently (to almost zero). For that reason, water extraction is unavoidable. But can the recent method of injecting a fracking fluid be trusted at an ultrahigh-pressure work site like this? And even if the tunneling goes well and we gradually learn to read the conditions in the surrounding environment, how is that to be used as the basis for a technical survey of the tunnel's structural safety, durability, and earthquake stability, and who is to be entrusted with such surveys? Technical details like these have not yet been supplied at all to civil engineering experts outside of the project. Nothing is published. Many experts have not even viewed the diagrams showing the section area of the tunnels involved (100 m<sup>2</sup>class).

We have already seen, there is precious little understanding in any of the newspapers of what civil engineering technology is about. As none of us engineers has had any experience either in tunneling deep under the Southern Alps, we should frankly admit as much to the media. And in all consequence, we should then be ready to say openly: “We do not have the confidence to tell you that we can bore a tunnel in a way that requires zero input of water from the Oi River System and will not lead to the loss of one waterdrop from the Fuji or Tenryu Rivers.” We cannot go for solutions to the Northern or Central Alps either. If we do something that leads to the drying up of the water-blessed Southern Alps, we will simply have gained nothing and lost everything.

When a private corporation comes up with a vision for a megalopolis of 650,000 people, all carefully matching the “super-megaregion” concept of the current government, how is it that we find not a single newspaper prepared to publicize this vision and invite public views on the pros and cons of a national land use reform to allow the transit of a vast flow of people both ways on this Linear axis, at a cost in electricity said to be no more than the outlay for one nuclear reactor? I fail to understand the reason for this. At a juncture like this, we civil engineers are the only ones in Japan qualified to say right out, “The work really is difficult. Let’s stop a while here, to pause and take stock.” The Coronavirus emergency provides us with a good opportunity for doing this, I feel. And if at the end it seems that a detour from Shinagawa via Kofu works best, well, that’s not bad, either. We can do that. We’ll lend you a hand!

Akira Asaoka

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

**Research Results in 2019**

**(1) Triaxial simulation of the failure of an unsaturated soil specimen through water absorption, using a three-phase elastoplastic finite deformation analysis taking account of inertia**

This research involved the numerical simulation of a triaxial compression test to destruct an unsaturated silt specimen through water absorption under a constant load by means of a reduction in suction and a rise in pore water pressure (a lowering in net stress). Figure 1 offers a comparison of the experimental and calculated results. Figure 2 shows internal loading conditions within the specimen. The calculated results achieved a good match with the characteristics of the experimental ones, showing plainly that the reduction in suction was a “softening behavior associated with plastic volume compression” due to the rise in saturation, while the rise in pore water pressure (the lowering in net stress) was another “softening behavior associated with the plastic volume expansion” that appears in

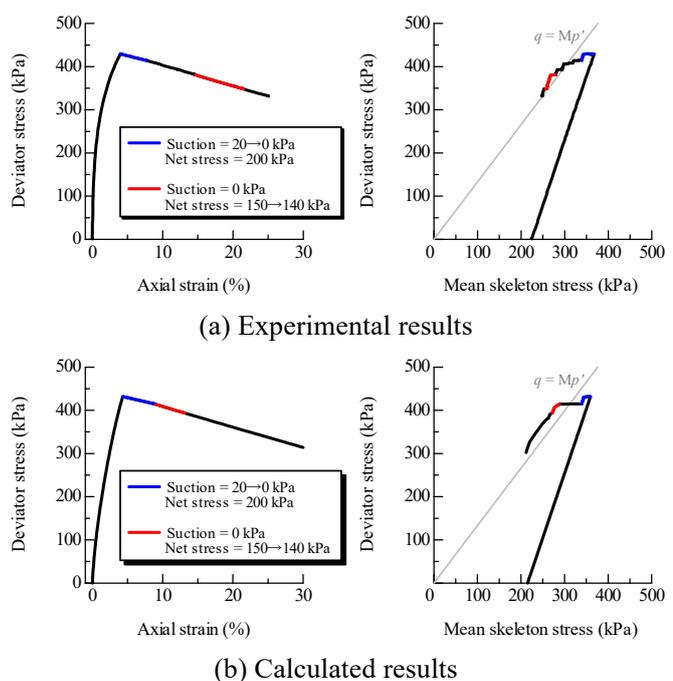


Fig. 1 Experiment to destruction through water absorption by means of reduction in suction and rise in pore water pressure

conditions of effective stress (soil skeleton stress) above the critical state line. In the destruction phase, the results also succeeded in replicating the course of axial displacements accompanying acceleration.

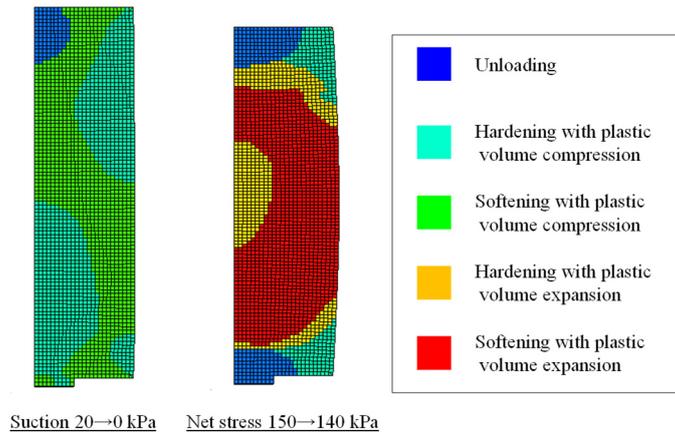


Fig. 2 Loading conditions within the specimen (Calculated results)

## (2) Dynamic u-w-p formulation-based immediate settlement analysis of a highly permeable clay

The soil-water coupling analysis of GEOASIA employs a u-p formulation, which assumes a static permeation of pore water. This made it difficult to apply the analysis to coupled problems involving dynamic pore water permeation, especially to dynamic deformation problems in highly-permeable soils. To overcome the limitation of u-p formulation, the analysis code has been rebuilt based on a u-w-p formulation which allows dynamic permeation of pore water.

Even confining the problem to a single dimension, u-w-p solutions shown in Fig. 3 consistently explain “consolidation” in low-permeable soils and “damped wave” in highly-permeable soils depending on a permeability coefficient. Besides, in the particular case of an instant loading problem in a saturated soil, the u-w-p equation system reduces to a mixed-type differential equation called a “damped wave equation” whose solution exhibits overdamping (consolidation) or underdamping depending on the permeability coefficient. The perfect correspondence of the analytical results to theoretical solutions of the damped wave equation was confirmed. As a next stage, there are plans to apply the analysis to problems of earthquake response in grounds containing gravel soils with high permeability.

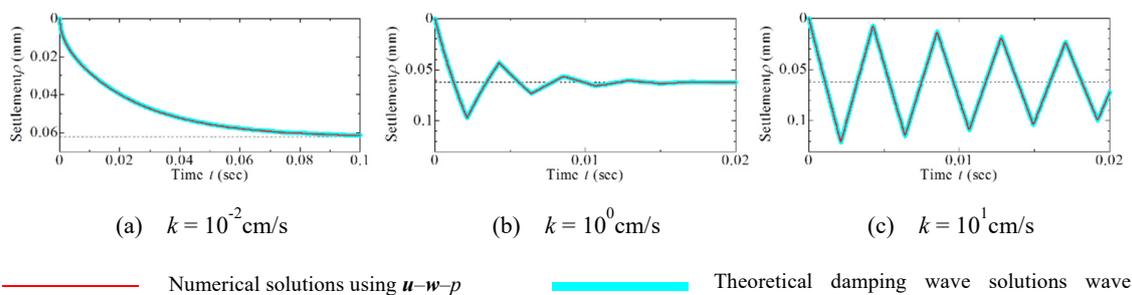


Fig. 3 The effect of permeability coefficient  $k$  on settlement – time relations

### (3) Numerical simulation relating to the formation of a normal fault group on an uplifted and inclined seabed

To assist with the replication of a normal fault formed when an undersea ground is inclined during an uplifting of the seabed, a numerical simulation was performed of uplifted and inclined grounds in varying degrees of solidification. From this, it was found that a normal fault group will only form in conditions where the ground is in a semi-solidified state. When one considers that a normal fault group formed in semi-solidified states in this way will tend to grow more solidified over time, making a slip back the other way unlikely, this suggests that a computation of this kind might also serve as an index to the length of time the progressive solidification process has been going on. It could thus be the key to a new scientific method for estimating the timespan over which a normal fault group has formed.

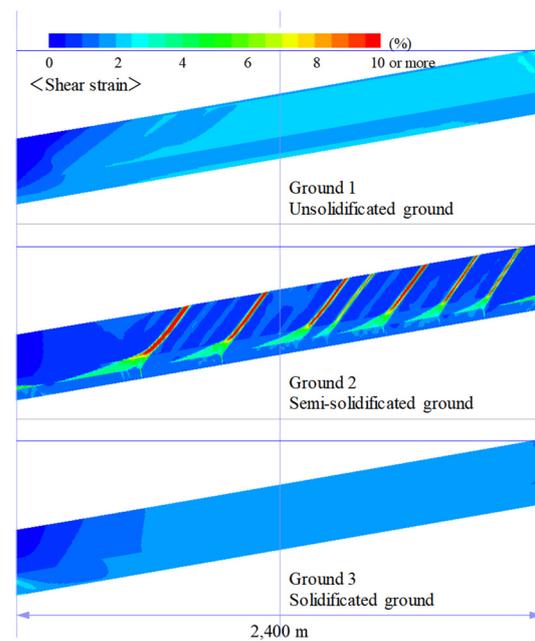


Fig. 4 States of a normal fault group on undersea grounds of varying degrees of solidification

### (4) Numerical analysis and discussion of the seismic resistance of a mudstone embankment, for two types of earthquake having different characteristics

After construction, a mudstone embankment deteriorates progressively in seismic resistance due to slaking. The research reported here attempted a numerical replication of conditions analyzed from a ground survey of a real embankment. An attempt was then made to assess the seismic resistance of the embankment to two level-two earthquakes differing in their event characteristics. The replication of the 1944 – Nankai Trough Earthquake involved repeated loadings over a protracted time. After the first wave had brought a decline in structural rigidity, a second wave led to extensive strain development. In the replication of the 1995 Hyogo-ken Nanbu Earthquake, there was no development of large-scale deformation as the seismic movement was short.

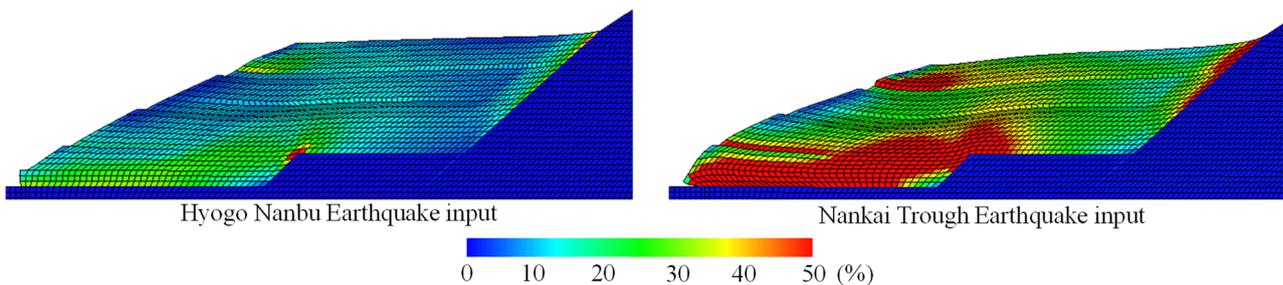


Fig. 5 Shear-strain distributions after the end of the earthquake

**(5) Analysis of the seismic response of an embankment built on an inclined ground and reinforced through a treatment of replacement / counterweight fill**

This is an analysis and discussion of the seismic resistance shown by an embankment constructed on an inclined ground and reinforced through a treatment of replacement / counterweight fill. Applying either of these treatments to an embankment will generally lead to a rise in its seismic resistance. Further, the greater the height and amount of counterweight fill applied, the larger in extent will be the reinforcement effect obtained for the counterweighted embankment. Put simply, the higher the counterweighting can be made, the better it will be for the embankment’s seismic resistance. As can be seen in the figure, the amount of shoulder displacement found in the treated case on the right can be confined to one-half of what it might be if no treatment were applied.

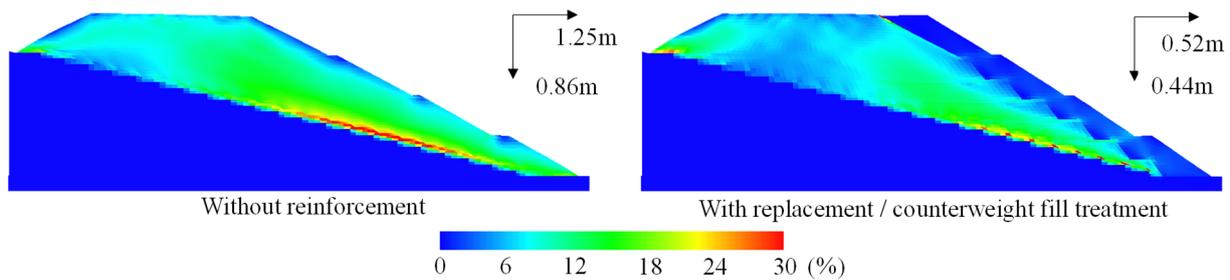


Fig. 6 Verified effects of the rise in seismic resistance obtained from a replacement / counterweight fill treatment

**(6) Behavior of a spherical gas holder on a soft soil foundation during and after an earthquake**

Research was conducted into the settlement behavior of a spherical gas holder supported by piles on a ground of layers of loose sand (N value 10 or less) and soft clay. Data from two L2 seismic movements, equal in their acceleration spectrums but differing in their event timing, were fed into the analysis and the response during and after the earthquake investigated in each case. One movement represented an epicentral earthquake, and the other a subduction-zone earthquake (Fig.7). In the epicentral case, the support piles suffered near-total destruction within 5 seconds of the start of the main earth movement, but the damage from the subduction-zone earthquake proceeded more gradually over a period of around 100 seconds. As the damage to the piles was nearly total, a further analysis was also performed for a hypothetical case in which support piles had not been present from the start. The results obtained from this were that for the data from the epicentral movement, almost the same amount of settlement would occur irrespective of whether there were support piles or not, but that for the subduction-zone data, the presence of the piles had a mitigating effect on the loss of rigidity in the soft clay layer, which was reflected in the smaller value of shear strain deformation. Even though the piles were almost totally destroyed in the earthquake, therefore, they clearly had a restraining effect on the amount of settlement undergone by the gas holder.

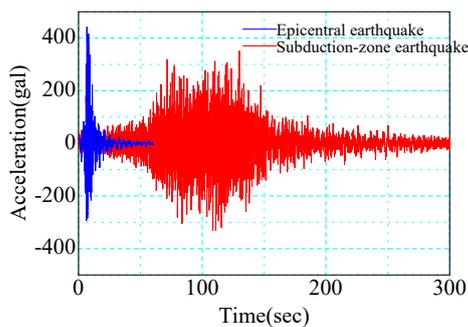


Fig. 7 The earth movement data used as input

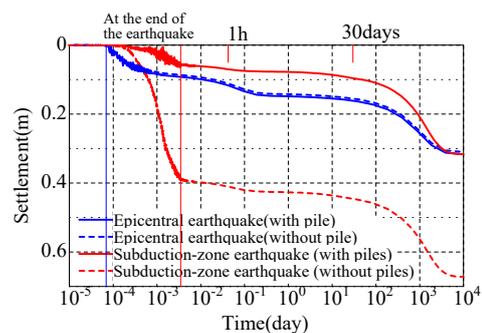


Fig. 8 Time history of the settlement

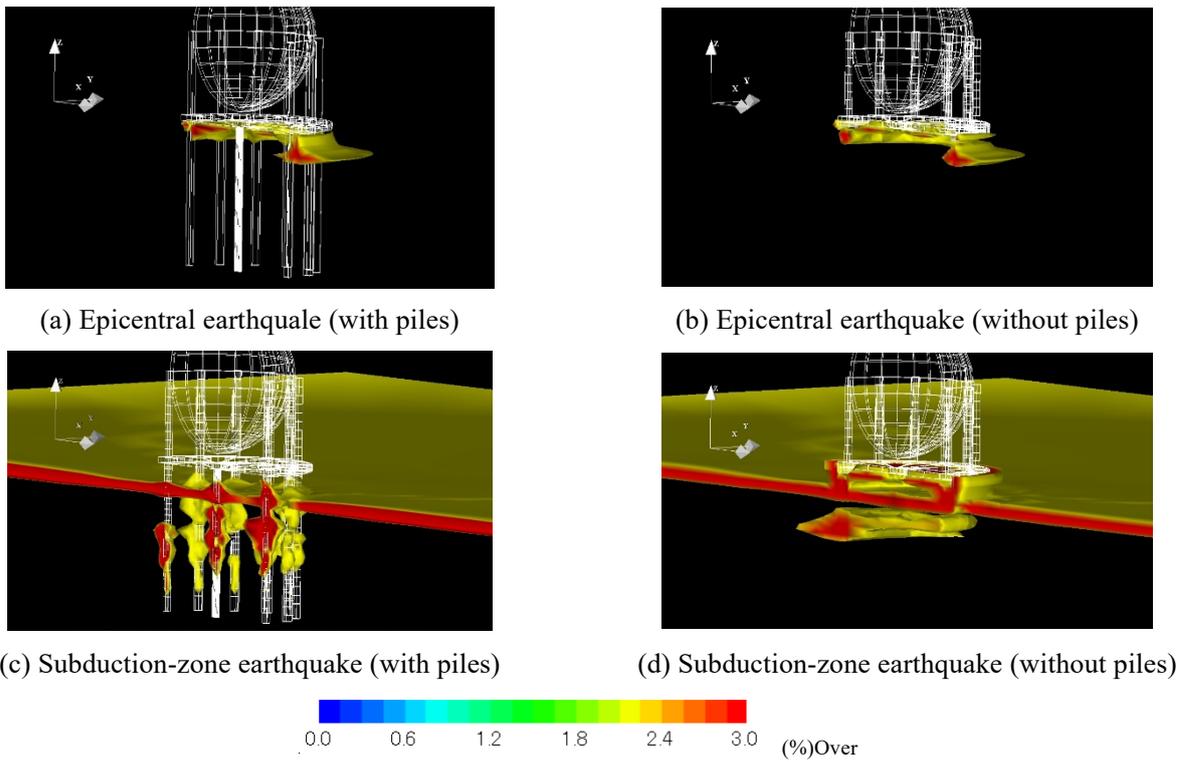


Fig. 9 Shear strain distributions at the end of consolidation (values of 2.2% and above are shown)

**(7) Numerical verification of the effectiveness of a new drainage method for protecting the underground portions of electrical utility poles from damage during ground liquefaction**

A numerical analysis was undertaken to verify the effectiveness of a new method of fitting drains to the underground parts of electrical utility poles as a way of preserving them from earthquake damage. It could be shown that by controlling the rise in excess pore water pressure at the time of an earthquake, it was possible to maintain the ground rigidity in the vicinity of the utility pole and thus to reduce the amount of swaying (inclination) suffered by the pole. The results showed a good match with results from separately conducted centrifugal model experiments, confirming that the fitting of drains can be an effective way of limiting damage to utility poles in areas exposed to ground liquefaction.

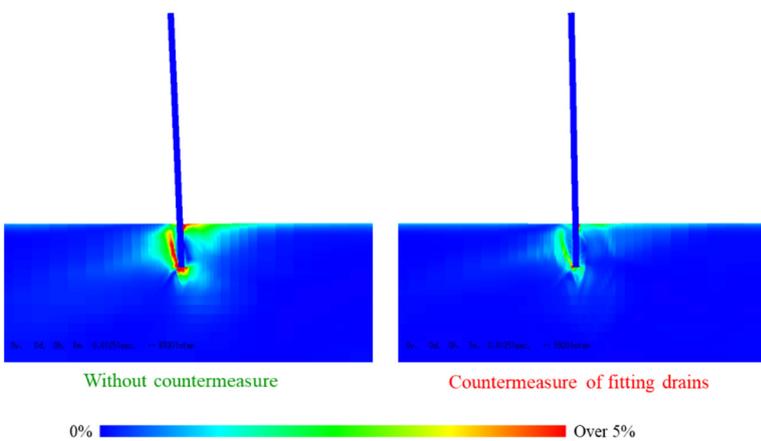


Fig. 10 Shear strain distributions 500 seconds after the occurrence of the earthquake

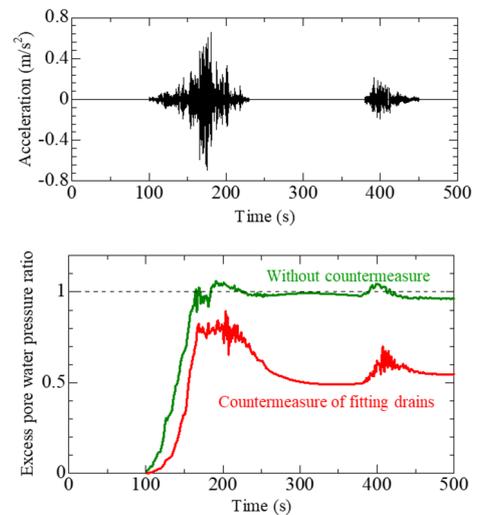


Fig. 11 Variation over time in excess pore water pressure

## Principal publications etc. in Academic Year 2019 (April2019-March2020)

### Academic papers:

【Soils and Foundations】 Development and verification of a soil–water coupled finite deformation analysis based on  $u-w-p$  formulation with fluid convective nonlinearity, *Soils and Foundations*, Vol.59, Issue. 4, 888-904, 2019.

【Journal of Applied Mechanics, Japan Society of Civil Engineers (A2)】 ①Reduction effects of liquefaction damage using small scale floating grid-type improvement for existing small scale structure, Vol. 75, No. 2, p. I\_329-I\_339, 2019. ②Influence of neighbor houses on liquefaction damage of detached houses, Vol. 75, No. 2, p. I\_401-I\_410, 2019. ③Soil-water-air coupled finite deformation simulation of model test on seepage failure of levee, Vol. 75, No. 2, pp. I\_379-I\_388, 2019.

### International conferences:

【16th Asian Regional Conference on Soil Mechanics and Geotechnical Engineering (Taipei, Taiwan, October,2019)】

①Mechanical properties of mudstone aggregate subjected to cyclic drying-immersion under constant vertical load, and seismic response analysis of mudstone embankments.②An analytical consideration on aftershock-induced expansion of liquefaction damage of sandy ground with groundwater-level rise due to main shock.③Numerical reproduction of Rayleigh and Love waves and assessment of their influences on subsurface ground damage.④ Numerical simulation of Riedel shear bands formation considering effects of geometrical barrier on strike-slip fault.⑤Analysis of the influence of phreatic surface position on the deformation of fill slope by using 1Gshaking table tests.⑥Earthquake resistance evaluation of aspherical gas holder considering its ultimate state due to liquefaction induced differential settlement of sandy ground.

### Domestic conferences:

【24th Conference of the JSCES (Saitama, May 2018)】 2 papers.

【2019 Japan Geoscience Union Meeting (Makuhari, May 2018)】 1 paper.

【22nd Symposium on Applied Mechanics (Saitama, June 2018)】 1 paper.

【54th Japan National conference on Geotechnical Engineering (Saitama, July 2019)】 16 papers.

【31st Chubu Geotechnical Symposium (Nagoya, August 2019)】 5 papers.

【74th Japan Society of Civil Engineers 2008 Annual Meeting (Takamatsu, September 2019)】 4 papers, etc.

## Editorial Afterword

The early summer rainy season (“tsuyu”) was unusually long and wet in 2020. And even after it ended and the hot summer weather set in, there was no let-up in coronavirus infections and the Research Society found itself obliged to hold its annual general event online. We found that there was also a good side to this, however, and for the following year, as well, we mean to explore various possibilities of face-to-face and online participation. Ten years after the founding of the GEOASIA Research Society as a formally registered organization, this is the next step facing us and one that we mean to rise to. As always, we trust in our members’ continuing support to see us over this latest challenge on our path. (Toshihiro Takaine)