SIMSG ISSMGE

ISSMGE Bulletin

Volume 14, Issue 1
February 2020

International Society for Soil Mechanics and Geotechnical Engineering
If the quality of the distributed file is not satisfactory for you, please access the ISSMGE website and download an electronic version.
www.issmge.org

TABLE OF CONTENTS

EDITORIAL BOARD

al-Damluji, Omar (Editor for Asia)
Bouassida, Mounir (Editor for Africa)
Cazzuffi, Daniele (Editor for Europe)
Chang, Der-Wen (Editor for Asia)
Davis, Heather (Editor for Africa)
Gonzalez, Marcelo (Editor for South America)
Jefferis, Stephan (Editor for Europe)
Leung, Anthony Kwan (Editor-in-Chief)
Ng, Charles Wang Wai (Ex-officio)
Rujikiatkamjorn, Cholachat (Editor for Australasia)
Sanchez, Marcelo (Editor for North America)
Siemens, Greg (Editor for North America)
Taylor, Neil (Ex-officio)
Baser, Tugce (Editor for YMPG)

Research highlights

Geotechnical Engineering Group, Kyoto University, Japan

Kyoto University was founded in 1897, the second university to be established in Japan. As of 2019, Kyoto University has ten Faculties, eighteen Graduate Schools, thirteen Research Institutes, which is the largest among Japanese Universities. A total of 10 Nobel Prizes have been awarded to both alumni and professors of Kyoto University.

The research group in Geotechnical Engineering consists of seven laboratories in the Graduate School of Engineering, the Graduate School of Agriculture, the Graduate School of Global Environmental Studies (GSGES) and the Disaster Prevention Research Institute (DPRI). The research activities of the group cover a wide range of areas in geotechnical engineering.

Geomechanics, Graduate School of Engineering
Makoto KIMURA [Prof.], Sayuri KIMOTO [Assoc. Prof.], Ryunosuke KIDO [Asst. Prof.]

Construction Engineering and Management, Graduate School of Engineering
Hiroyasu OHTSU [Prof.], Thirapong PIPATPONGSA [Assoc. Prof.], Takafumi KITAOKA [Asst. Prof.]

Geofront System Engineering, Graduate School of Engineering
Mamoru MIMURA [Prof.], Yosuke HIGO [Assoc. Prof.], Mai SAWADA [Asst. Prof.]

Urban Management Systems, Graduate School of Engineering
Kiyoshi KISHIDA [Prof.], Yasuo SAWAMURA [Assoc. Prof.], Yusuke MIYAZAKI [Asst. Prof.]

Research highlights

Geotechnical Engineering Group, Kyoto University, Japan (Con't)

Agricultural Facilities Engineering, Graduate School of Agriculture
Akira MURAKAMI [Prof.], Kazunori FUJISAWA [Assoc. Prof.]

Environmental Infrastructure Engineering, Graduate School of Global Environmental Studies
Takeshi KATSUMI [Prof.], Atsushi TAKAI [Assoc. Prof.]

Geotechnics for Geo Hazard Mitigation, Disaster Prevention Research Institute
Ryosuke UZUOKA [Prof.], Kyohei UEDA [Asst. Prof.]

Geotechnical research group affiliated to the Graduate School of Engineering (as of Feb. 2020).

Research Areas
Research areas include soil and rock mechanics, soil structures, foundations, soft ground, tunneling, monitoring, construction management, agricultural facilities, environmental engineering, energy and geo hazards. Current projects focus primarily on the following topics.

Soil and Rock Mechanics from Micro to Macro

1. Three-phase microstructural changes in partially saturated sand (R. KIDO and Y. HIGO)
Earth structures such as road and railway embankments exist under partially saturated state; pore spaces between grains are filled with water and air. The strength and stiffness of partially saturated soil are enhanced by suction; however, it exhibits brittle mode of failure with clear shear band due to loss of suction caused by water infiltration or shearing. Macroscopic behaviors of partially saturated soil strongly depend on microscopic three-phase interactions. It is important, therefore, to clarify the failure mechanism of partially saturated soil from a microscopic viewpoint. Our research team has investigated the failure mechanism of partially saturated soil by conducting triaxial compression tests using x-ray micro tomography (Fig. 1) (Kido et al. 2020, Kido and Higo 2019, Higo et al. 2018, Higo et al. 2013, Higo et al. 2011).

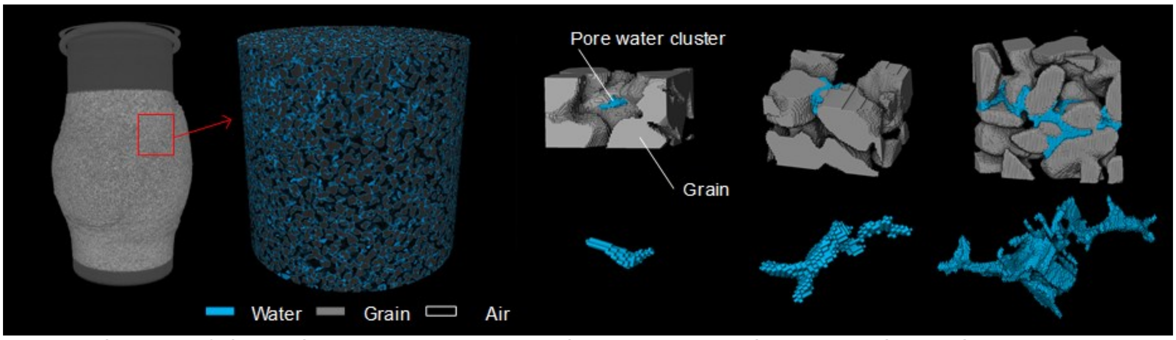

Figure 1. Visualization of three-phase microstructures and water meniscus between soil particles

Research highlights

Geotechnical Engineering Group, Kyoto University, Japan (Con't)

2. Large deformation analysis using Material Point Method (Y. HIGO)
Recently, particle methods and mesh-free methods have been widely used for simulating extremely large deformation problems in geotechnical engineering. Material Point Method, which is a particle method originally developed for single-phase solid mechanics, has been extended to a multi-phase coupling analysis method considering effect of partial saturation and elasto-plastic constitutive relations. The extended method has been applied to slope failure of embankments subjected to infiltration of water and liquefaction-induced large deformation of river levees (Fig. 2) (Kiriyama et al. 2018, Higo et al .2010).

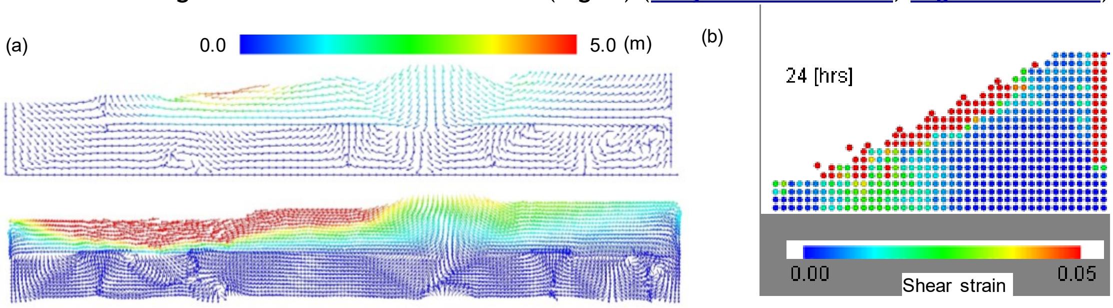

Figure 2. a) Liquefaction-induced deformation: FEM (upper) vs. MPM (lower); b) Slope failure caused by infiltration

3. Mechanical and hydro-mechanical behaviors of fractured rock masses (K. KISHIDA)
When discussing the construction and the maintenance of tunnels and underground caverns and the slope stability, the mechanical and hydro-mechanical behaviors of fractured rock masses should be clarified. The mechanical and hydro mechanical behaviors of fractured rock masses are strongly affected by those of the rock joints and/or fractures. Through experimental works on single joints and/or fractures, the mechanical and hydro-mechanical behaviors of single joints are studied (Kikumoto et al. 2017).

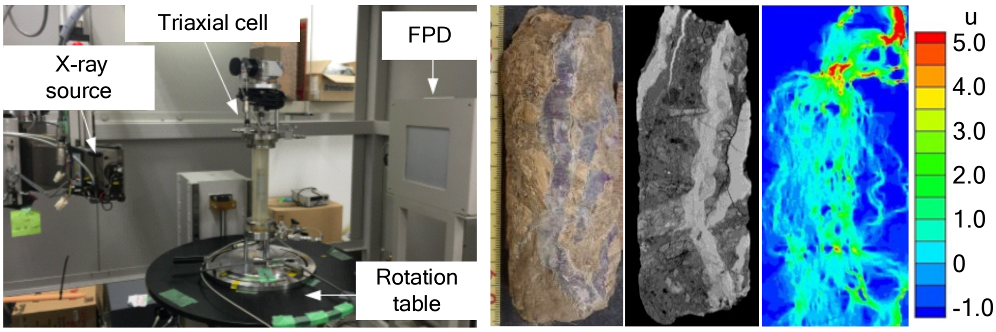

Figure 3. Analysis on discontinuous rock by microfocus X-ray CT

Soil – structure interaction

1. Study on interaction between soil and structure (arch culvert, piles) (Y. SAWAMURA, K. KISHIDA and M. KIMURA)
Precast arch culverts (Fig. 4), superior in appearance and labor-saving, have been encouraged to use for the purpose of the promotion of the productivity improvement in earthwork in Japan. Its seismic performance is, however, a significant issue in Japan where earthquake occurs frequently. Our research team has investigated the seismic performance of the precast arch culvert in culvert horizontal and longitudinal direction using dynamic centrifuge tests and numerical simulations (e.g., Sawamura et al. 2015). Based on the current design method, pile foundations built in soft ground or liquefiable ground have a large substructure, resulted in increasing construction cost. Therefore, the number of piles and footing can be reduced by improving soil around piles (Fig. 5). The influence of the difference in ground improvement parameters such as strength and range on the behavior of the group pile foundation has been investigated by conducting centrifuge model tests and numerical simulations (e.g., Isobe et al. 2014).

Research highlights

Geotechnical Engineering Group, Kyoto University, Japan (Con't)

Figure 4. Centrifuge model test (arch culvert)

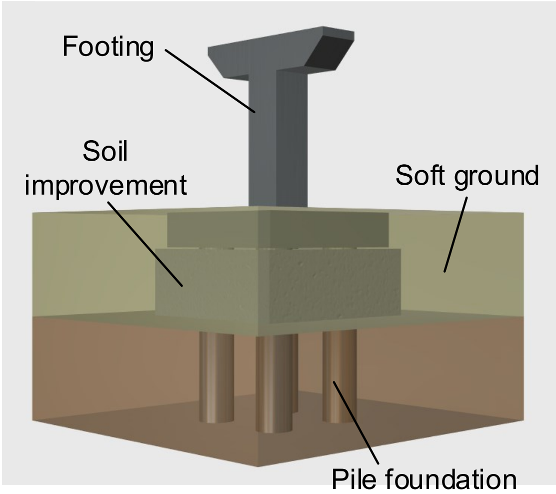

Figure 5. Group pile with soil improvement

2. Design, construction, and maintenance of underground structures (K. KISHIDA and M. KIMURA)

The effective design, safety construction, and smart maintenance of geo-infrastructures and rock infrastructures are studied here. For examples, when shallow overburden tunnel is to be excavated in an urban area, the auxiliary method that will be applied should be considered. When an area is to be excavated in deep underground, seepage and the huge earth pressure that will be encountered should be considered (Cui et al. 2017).

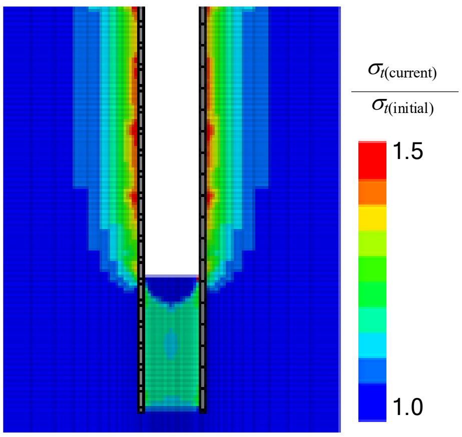

Figure 6. Excavation analysis on vertical shaft

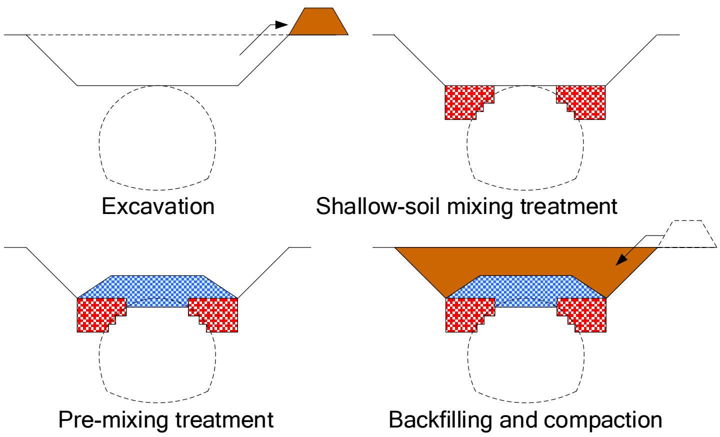

Figure 7. Pre-improving ground for shallow overburden tunnel

3. Clarification of seismic performance of reinforced earth wall (Y. SAWAMURA and M. KIMURA)

The steel-strip reinforced earth wall (SSREW) was developed in France in mid-1960 and currently has been used widespread all over the world. Although SSREW is well recognized as having high seismic resistance structure, mechanical role of the reinforcing material laid in the active failure zone and the mechanical role of the reinforcing material against the integrity of the SSREW have not been sufficiently verified. Through dynamic centrifuge tests and the numerical analyses, these unknown seismic behaviors due to dynamic soil structure interaction are being investigated (Sawamura et al. 2019).

Research highlights

Geotechnical Engineering Group, Kyoto University, Japan (Con't)

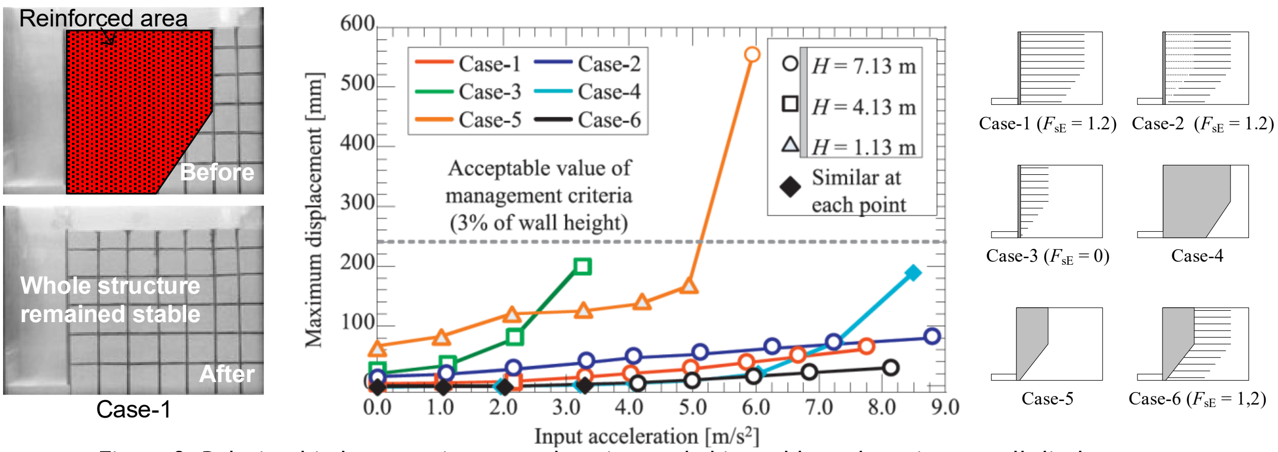

Figure 8. Relationship between input acceleration at shaking table and maximum wall displacement.

4. Conservation and restoration of tumulus mounds (M. SAWADA and M. MIMURA)
Geotechnical aspects of conservation and restoration of tumulus mounds, known as the oldest earth structures, have been studied. For controlling damages due to natural hazards and man-caused destruction and passing the tumulus mounds to future generations, controlling of the stability and infiltration of the mounds and hydrothermal environment in chambers have been studied based on geotechnical experiments and numerical analyses (Sawada et al. 2015, Sawada et al .2017, Sawada et al 2018).

Figure 9. Preservation of tumulus mound using capillary barrier

5. Theoretical analysis of earth pressure distribution (T. PIPATPONGSA, T. KITAOKA and H. OHTSU)
Load transmission in a translational retaining wall (Khosravi et al. 2016) and conical sand heaps (Nguyen et al. 2018) are thoroughly investigated by both theoretical and experimental approaches. Achievements of these researches reveal new theoretical solutions for describing earth pressure distribution which cannot be clearly derived in the past decades.

Research highlights

Geotechnical Engineering Group, Kyoto University, Japan (Con't)

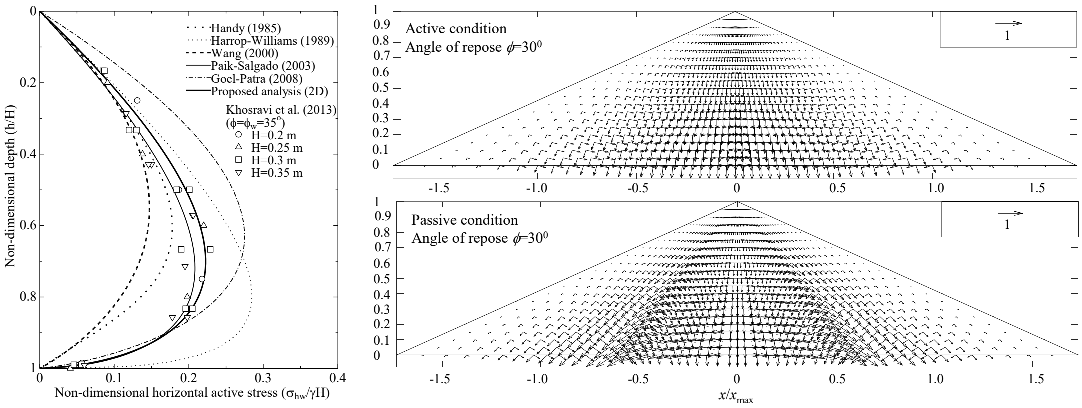

Figure 10. a) Theoretical prediction for the distributions of horizontal active stress compared with laboratory-scale measurements; b) Trajectory of principal stresses in conical sand heap under active and passive conditions.

6. Numerical and physical models of undercut slope (T. PIPATPONGSA)

In order to clearly observe pre-failure mode, failure-triggering mode and post-failure mode, physical model (Khosravi et al. 2016) with various techniques of measurement and numerical models (Ukritchon et al. 2019) using 3D finite element analysis have been developed for slope stability problems. The immediate outcome of this research is a novel design method of undercut slopes in an open-pit mine.

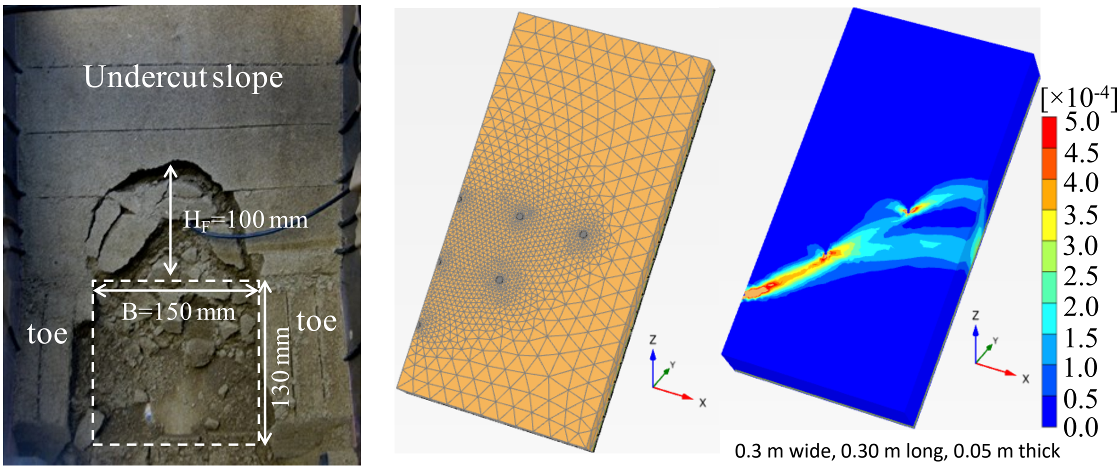

Figure 11. a) Arch-formed failure observed in the final step of an in-flight excavation centrifuge model; b) Incremental deviatoric strain of FEM model with 9 shear pins making a reverse triangle.

Energy Geotechnics

1. Mechanical behavior of gas hydrate-bearing soils and its numerical modelling (S. KIMOTO)

In March 2013, the world's first offshore gas production from marine methane hydrate (MH) deposits was conducted in Eastern Nankai Trough off the Pacific coast of Japan. There still exists a lot of uncertainties regarding the mechanical behavior during methane gas production. CO_2 hydrates have been also attracting attention from the viewpoint of CO_2 storage (CCS). To investigate the mechanical behavior of hydrate-bearing sediments, compression and creep tests have been conducted synthetic CO_2-hydrate-bearing sand specimens using low-temperature and high-pressure triaxial apparatus (Fig. 12 a), Iwai et al. 2019). In addition to the laboratory tests, a chemo-thermo-mechanically coupled numerical analysis methods have been developed in order to reproduce the dynamic behavior during earthquakes and sand production (Fig. 12 b), Akaki and Kimoto 2019).

Research highlights

Geotechnical Engineering Group, Kyoto University, Japan (Con't)

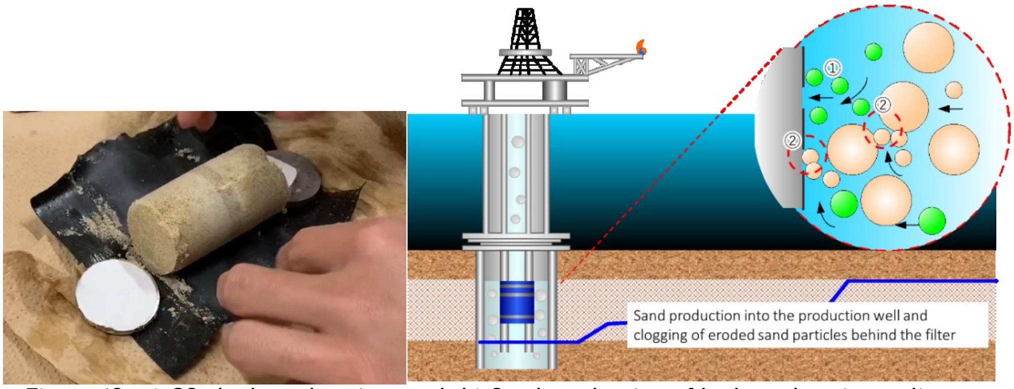

Figure 12. a) CO_2-hydrate-bearing sand; b) Sand production of hydrate-bearing sediments

2. Elucidation of hydraulic and mechanical properties of rock under THMC coupled conditions (K. KISHIDA)

When considering the geological isolation of high-level radioactive waste and CO2 geological storage, the integration of various types of information through geomechanics, rock mechanics, fluid mechanics, thermal dynamics, and geochemistry is required. The mechanical and hydro-mechanical properties of jointed rock masses are clarified through an advanced approach and fundamental experiments with iPSACC (interface for Pressure Solution Analysis under Coupled Conditions) coupling the thermal (T), hydro-mechanical (H), mechanical (M), and chemical (C) properties is developed (Ogata et al. 2018).

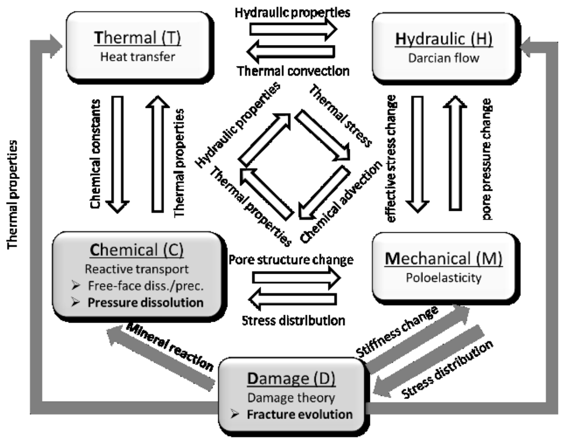

Figure 13. Multi-physics interactions in THMC simulator

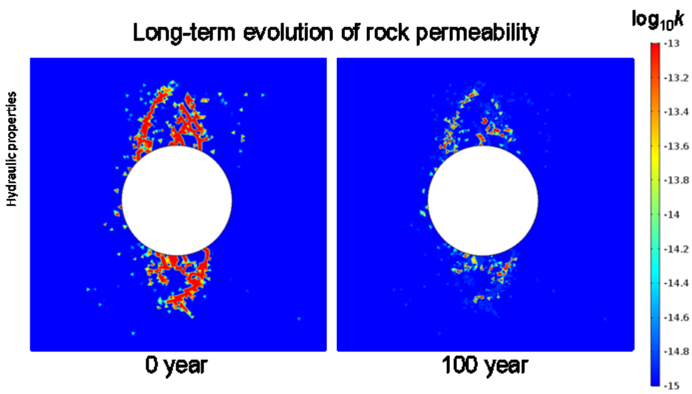

Figure 14. Predicted long-term permeability change of rock mass

Field Measurement and Geo Informatics

1. Characteristics of fine particle distribution at cut slope and fill slope comprising weathered granite (H. OHTSU, T. PIPATPONGSA and T. KITAOKA)

In this study, fine particle distribution in artificial slopes comprising weathered granite, which may affect rainfall-triggered landslide, was investigated comprehensively, based on electrical resistivity, soil composition and unsaturated soil properties. The results showed that while degree of saturation plays a key factor on electrical resistivity in unsaturated soil, it has close correlation to pore-size distribution. Therefore, it can be considered that electrical prospecting is an effective method to investigate distribution of both coarse particle and fine particle. In addition, it was also pointed out that there is possibility that fine particle fraction involved in soil poorly compacted in artificial slopes may be eroded due to rainfall infiltration (Ohtsu et al. 2018).

Research highlights

Geotechnical Engineering Group, Kyoto University, Japan (Con't)

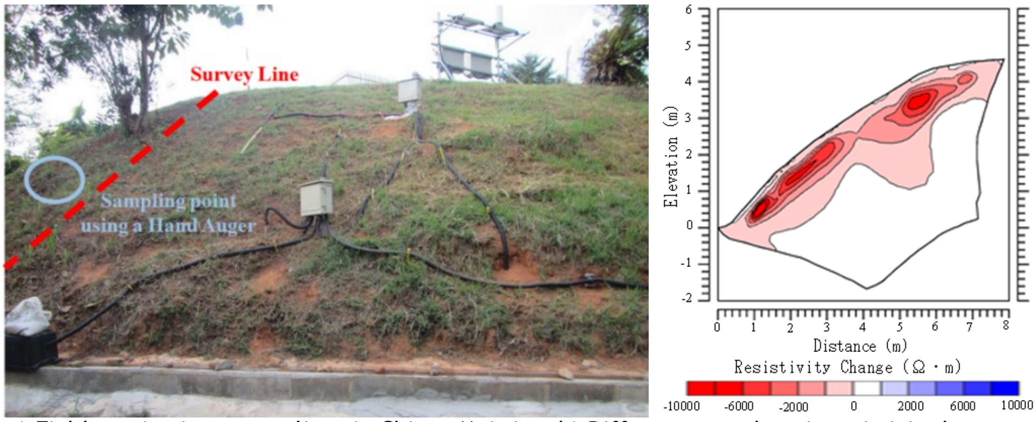

Figure 15. a) Field monitoring survey lines in Chiang Mai site; b) Difference on electric resistivity between dry season and rainy seasons.

2. Applicability of neural network in rock classification of mountain tunnel (H. OHTSU and T. KITAOKA)
In construction projects of mountain tunnels, with a purpose of improving accuracies of rock classifications in preliminary survey, we have studied applicability of Artificial Neural Network (ANN). One characteristics of ANN is that it does not require defining clear formula correlating data input and output, by using its learning function. Leveraging the characteristics and accuracy of rock classification were improved by using geophysical datasets (seismic velocity and resistivity) at a tunnel face and surroundings. Also, ANN has a problem of reduced applicability caused by over learning to training data. It is possible to avoid the over learning problem by increasing training dataset, but it is not easy to accumulate complete dataset of geophysical properties and actual rock classification obtained in construction stage. We found that it is important to collect various tunnel data without much deviation, for accumulating training datasets effectively in the future (Ohtsu et al. 2018).

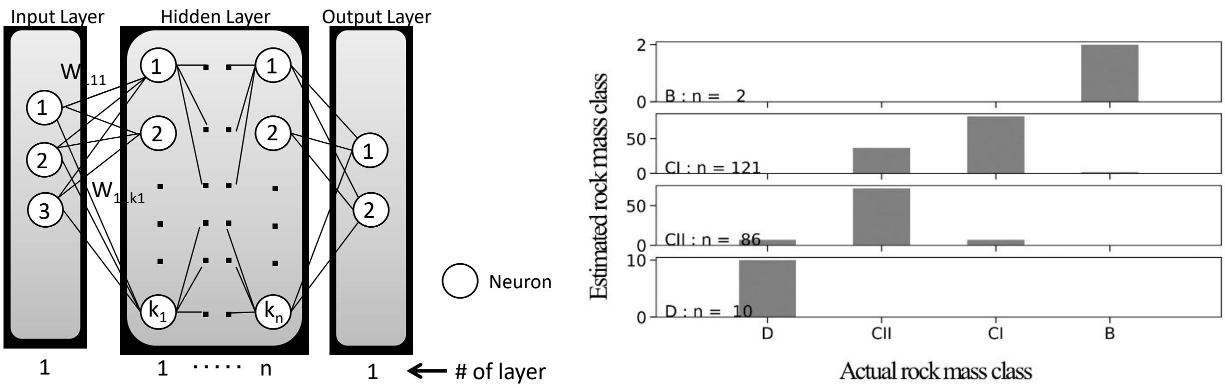

Figure 16. a) Structure of ANN; b) Comparison with predicted and real rock classification

3. 3D modeling of grounds using in-situ investigation and geo-informatics database (M. MIMURA and Y. HIGO)
Professor Mamoru Mimura deals with various kinds of geotechnical issues including long-term settlement of reclaimed land, development of in-situ investigation technique, development and utilization of geo-informatics database, and preservation of historical structures. A recent research topic concerns 3D modeling of grounds using in-situ investigation and geo-informatics database, and its application to disaster mitigation such as seepage failure of river levees and seismic ground motion (Ichimura et al. 2019, Kudoh et al. 2019).

Research highlights

Geotechnical Engineering Group, Kyoto University, Japan (Con't)

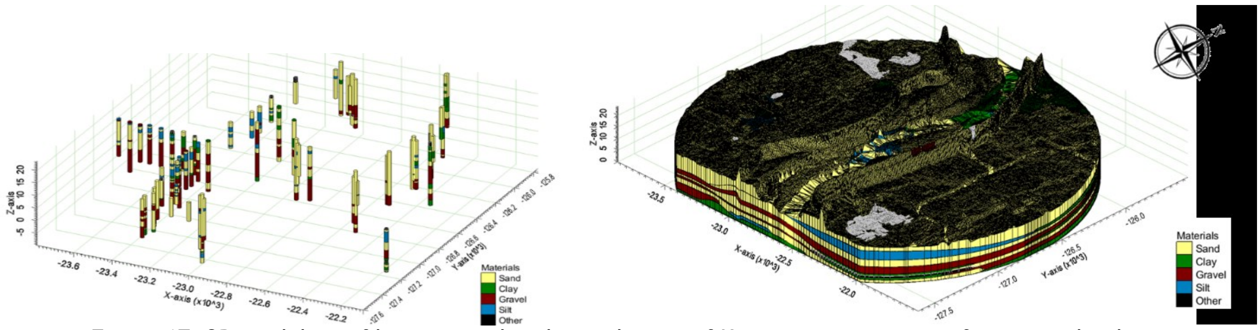

Figure 17. 3D modeling of base ground and river levees of Kizu river using geo-informatics database

Agricultural Facilities Engineering

The research group of Agricultural Facilities Engineering is belonging to the department of agriculture, and working on advanced management of structures for agricultural purposes, such as embankment dams. The detailed research topics are categorized into inverse analysis and health monitoring of irrigation structures based on Bayesian inference, deformation and dynamic response of soil and concrete structures, microscopic numerical simulation of solid-fluid interaction, modeling of soil erosion, and plant-soil interaction.

1. Imaging of embankment interior (K. FUJISAWA and A. MURAKAMI)
Techniques imaging inside of soil structures or the ground such as geophysical exploration play an important role in health monitoring. The research group has developed a probabilistic inversion method which enables the stiffness (elastic modulus) of such structures to be estimated though the elastic wave propagation. Fig. 18 shows a typical result of identified spatial distribution of elastic modulus in a reconstructed embankment consisting two layers (Michael et al. 2019).

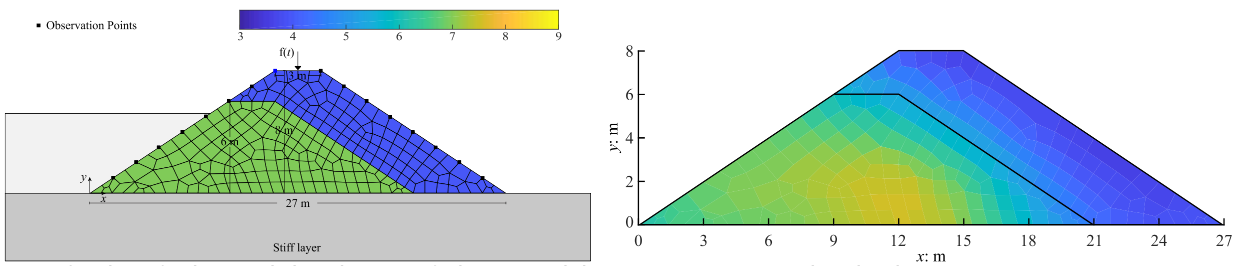

Figure 18. Identified spatial distribution of elastic modulus in a reconstructed embankment

2. Modeling of soil erosion (K. FUJISAWA and A. MURAKAMI)
Erosion of soils is a complex phenomenon related to hydraulics and soil mechanics. Fig. 19 a) describes the concept that divides the phenomenon into individual motion of soil particles and continuum deformation. Hydraulic approaches are helpful for the individual particle motion, and continuum soil mechanics can be applicable to the deformation of soil surface. Fig. 19 b) shows an experimental apparatus for capturing the incipient motion of sand particles subjected to surface and seepage flows. The experimental investigation of soil erosion subjected to seepage flow are ongoing as well as constitutive modeling of soil surface (Jewel et al. 2019).

Research highlights

Geotechnical Engineering Group, Kyoto University, Japan (Con't)

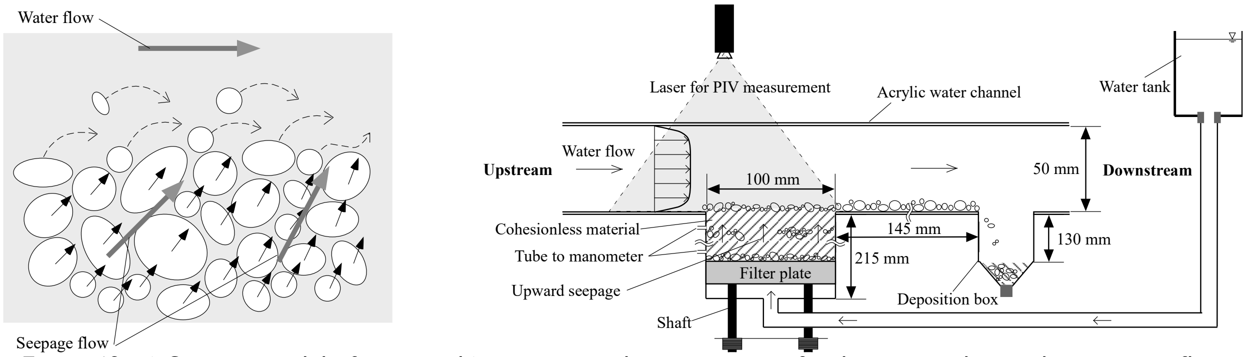

Figure 19. a) Concept model of erosion; b) experimental investigation of soil erosion subjected to seepage flow

Geoenvironmental Engineering

1. Anthropogenic and geogenic contamination: characterization, utilization, and remediation (T. KATSUMI and A. TAKAI)

When selecting adequate techniques to solve problems of anthropogenic and geogenic contamination of soil and/or groundwater, the mobility of the contaminants, their mechanisms, and the reliability of the countermeasures should be scientifically clarified. We are experimentally and analytically studying the mobility of heavy metals with an emphasis on geogenic contamination (Katsumi 2015). The effectiveness of countermeasures such as vertical cutoff walls (Takai et al. 2019) and attenuation layer (Gathuka et al. 2019) (Fig. 20) are also evaluated by laboratory and field tests. These research activities directly contribute to establishing legal frameworks, such as Soil Contamination Countermeasures Act, for sustainable ground remediation and utilization in Japan. In addition, in recognition of his scientific and practical contribution, Dr. Takai won the ISSMGE Outstanding Young Geotechnical Engineer Award in 2017.

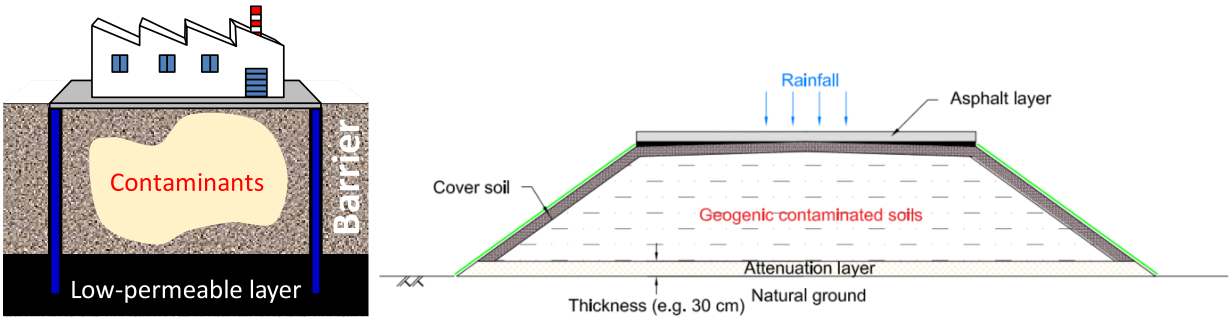

Figure 20. Countermeasures for geoenvironmental contamination vertical cutoff walls (left) and attenuation layer method (right).

2. Geotechnical utilization of by-products and wastes (A. TAKAI and T. KATSUMI)

The social and economic system is now shifting to attain the SDGs by promoting further resource recycling and the maintenance of existing infrastructures. In this laboratory, the application of recycled wastes as geomaterials is studied from the mechanical and geoenvironmental viewpoints (Fig. 21). In addition, in order to contribute to adequate management of disaster waste generated through huge catastrophes, recovery of soils from disaster waste as geomaterial, development of disaster waste management system using ICT, and secure disposal of soils and wastes containing nuclides are also being studied (Katsumi et al. 2017).

Research highlights

Geotechnical Engineering Group, Kyoto University, Japan (Con't)

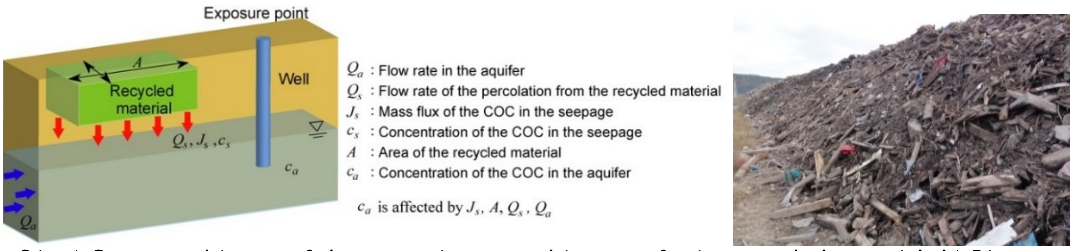

Figure 21. a) Conceptual image of the geoenvironmental impact of using recycled material; b) Disaster waste generated through the 2011 off the Pacific Coast of Tohoku Earthquake.

3. Sustainable waste treatment and management (A. TAKAI and T. KATSUMI)
Even with the upmost effort to reduce waste generation in our daily lives, a certain amount of waste is going to be generated into the future, unfortunately. This laboratory is performing a series of research related to the hydraulic performance of geosynthetic clay liners (GCLs) (Naka et al. 2019) (Fig. 22 a)), the mobility assessment of toxic elements in the sites, the mechanical properties of waste ground (Nguyen et al. 2015), and the risk assessment of the utilization of closed landfill sites (Fig. 22 b)).

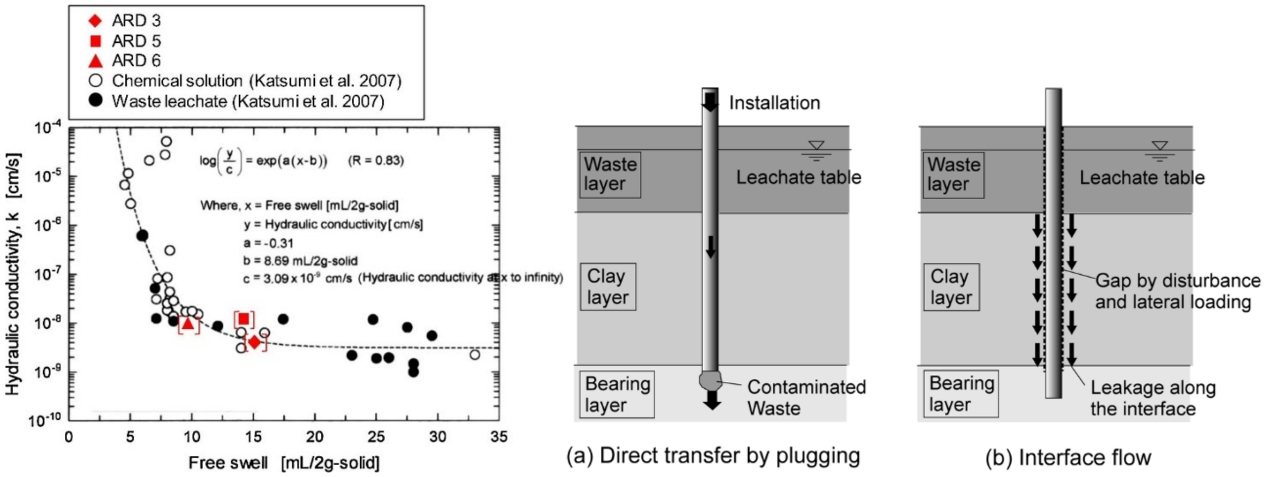

Figure 22. a) Relationship between hydraulic conductivity and free swell volume for non-prehydrated powder bentonite (Naka et al. 2019); b) Geoenvironmental risks of pile installation at closed coastal landfill sites.

Geotechnics for Geo Hazard Mitigation

Main research interests are combined disasters induced by rainfall, earthquake and tsunami etc. To better understand the complex behavior of soil-structure systems under various external forces, Prof. Uzuoka and Asst. prof. Ueda have been engaged in the advancement of constitutive modeling of geomaterials including partially saturated soils, and the development of innovative centrifuge modeling. A recent research topic concerns the reliability improvement of numerical simulations based on Uncertainty Quantification (UQ) with Verification and Validation (V&V) method.

1. Seismic behavior of partially saturated ground (R. UZUOKA and K. UEDA)
The role of pore air pressure on the seismic behavior of partially saturated soils is investigated through recent numerical simulations with three-phase and simplified two-phase coupled analyses (Uzuoka et al. 2019). Constitutive modeling of partially saturated soils has been developed, along with governing equations for the dynamic behavior of such soils based on porous media theory. This research focuses on the validity of three-phase coupled analysis and the applicability of simplified two-phase coupled analysis through simulations of cyclic triaxial tests and seismic behaviors of horizontal ground and embankments.

Research highlights

Geotechnical Engineering Group, Kyoto University, Japan (Con't)

2. Seismic behavior of inherently anisotropic ground (K. UEDA)

Inherent anisotropy is a crucial aspect to consider for an improved understanding of the strength and deformation characteristics of granular materials. Its influence on ground seismic responses was examined through a series of dynamic centrifuge model tests on liquefiable level sand deposits (Ueda et al. 2019). During the model setup, different deposition angles (between 0 and 90 degrees) were achieved using a specially designed rigid container. The dynamic responses under tapered sinusoidal waves demonstrate that a sandy ground, deposited at a higher angle (i.e., closer to 90 degrees), is more susceptible to liquefaction.

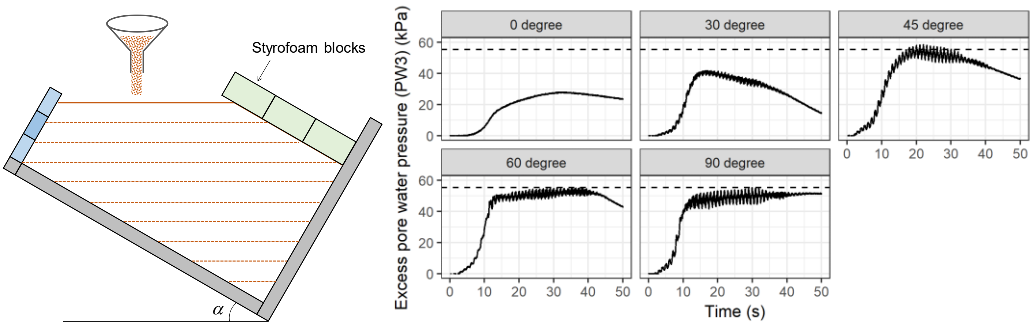

Figure 23. a) Conceptual diagram showing model preparation with a α-degree deposition angle from the horizontal; b) Measured excess pore water pressure time histories during pressure build-up phase at the mid-depth of ground.

3. Generalized scaling law for centrifuge modeling (K. UEDA)

The generalized scaling law is based on the concept of two-stage scaling and allows currently available centrifuge facilities to model a large-scale prototype subject to earthquake motions. Its application to the fully nonlinear regime of a soil-structure system, i.e., a pile model embedded in an inclined ground subject to liquefaction-induced lateral spreading, was investigated (Ueda et al. 2019). The seismic responses demonstrate that the generalized scaling law is applicable to the fully nonlinear regime of soil-structure systems subject to the cumulative shear strain in the order of 10% due to cyclic mobility of sands during earthquakes.

4. Liquefaction Experiments and Analysis Projects (LEAP) (K. UEDA and R. UZUOKA)

The Liquefaction Experiments and Analysis Project (LEAP) is a joint international project that pursues the verification, validation and uncertainty quantification of numerical liquefaction models. As part of LEAP-GWU-2015, LEAP-UCD-2017, and LEAP-ASIA-2019 campaigns, a series of centrifuge model tests and numerical simulations have been developed at the Disaster Prevention Research Institute, Kyoto University to simulate the dynamic behavior of a submerged sloping sandy deposit (Ueda et al. 2019, Vargas et al. 2019). The results are intended to compose part of a reliable database in the development of current and future V&V processes of liquefaction models.

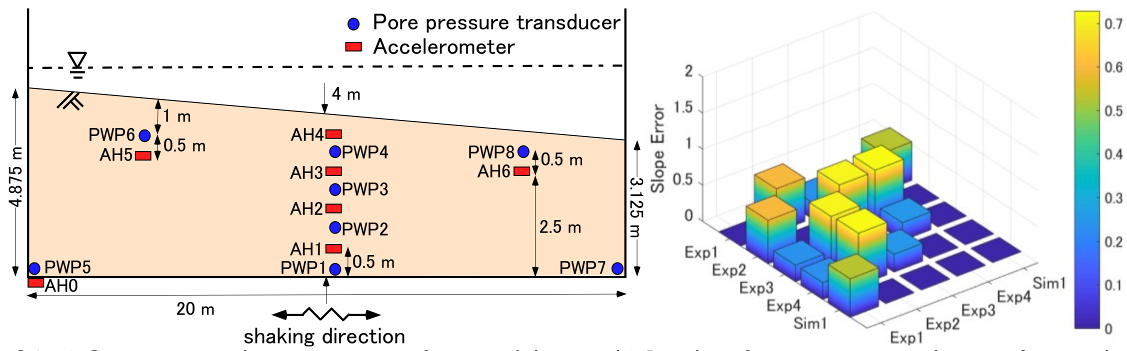

Figure 24. a) Cross-section diagram in centrifuge model tests; b) Results of quantitative evaluation for accelerations at AH4.