New Exploratory Research (Project No.: 2020H-03)

Project name: リングせん断試験に基づいた粘土質土のクリープ挙動の解明および斜面崩壊時刻予測の高度化
Principal Investigator: Chengrui Chang
Affiliation: Division of Earth and Planetary Sciences, Graduate School of Science, Kyoto University
Name of DPRI collaborative researcher: Gonghui Wang
Research period: 01 04, 2020 ~ 31 03, 2021
Research location: Disaster Prevention Research Institute, Kyoto University, Gokasho, Uji, 611-0011, Japan
Number of participants in the collaborative research: 2 (DPRI: 2 non-DPRI: 0)

- Number of graduate students: 1 (Masters: 0 Doctoral students: 1) (Included number)
- Participation role of graduate students [Experimental tests, Investigation, Lab assistance, Data analysis]

Anticipated impact for research and education

Many models had been proposed for predicting the time of failure of landslides because it is of great social and economic significance for preventing or mitigating landslide disasters. Nevertheless, the basic physical mechanisms, which regulate the evolution to catastrophic failure for creeping slopes, remain elusive. To improve the precision of time prediction, understanding the physical background of prediction models is essential. The present study employed innovative methods to mimic rainfall-triggered landslides and suggests a 3-stage tertiary creep model and its implications for time prediction. On the other hand, this study can also provide the research community with an effective and experimental platform to address these challenges regarding granular materials and dynamic processes. The project can be used to train graduate students to comprehend the cutting-edge field of earth surface processes and advanced skills.

Research report

(1) Purpose

The pre-failure motion of landslides is complex and does not always exhibit a unique time-dependent behavior. The nonlinearity of time-displacement relation, geometrical and geological complexities, and seasonal variations make the time prediction of landslides difficult. Among the empirical time-prediction models, Voight's model is more physically based and enables a promising forecast of the failure time of slopes. However, the physical background of key parameters is poorly understood. This research aims to investigate the underlying mechanisms driving landslide dynamics and to understand possible physical factors behind the parameters (α and A) in Voight model, by developing an improved testing system with well-controlled hydro-mechanical conditions to mimic the rainfall-triggered landslides.

(2) Summary of research progress

The mixture of silica sand No.7 (SS7) with different content of bentonite (SS7: Bentonite = 10:0, 9:1, 8:2, and 7:3, respectively) was used for ring shear tests. A natural clayey soil (Kinokawa sample) comprising highly weathered schist was taken from a nature landslide site in Kinokawa area, Wakayama Prefecture. And a clayey sample of weathered serpentinite was also used.

Three experimental approaches were conducted to reproduce the creep behavior on the pre-consolidated samples. We employed a normal-stress-controlled method to decrease the normal stress on the mixtures (SS7 + Bentonite) or serpentinite in a drained condition. Similarly, we conducted the pore-water pressure-controlled tests on Kinokawa sample to mimic the creep behavior of slopes due to the increasing groundwater table. The target of the normal-stress or pore-water pressure controlled method is to decrease the effective normal stress to trigger material failure. And the shear-stress-controlled tests were conducted on Kinokawa sample and silica sand. Creep behavior was successfully reproduced on soils in a hydro-mechanical regime. The parameters are determined by a retrospective analysis of the kinematic feature in tertiary creep following the Voight model.

(3) Summary of research findings

The representative result is exampled in Figure 1 to reveal the kinematic property of Kinokawa sample in a pore-water pressure controlled test with the monotonically increased pore-water pressure. Main findings are summarized based on pore-water pressure controlled tests : (1) an inflection point in the time-velocity curve in tertiary creep which indicates the kinematic behavior changes (Figs. 1a-1b); (2) a 3-stage log-linear pattern for the velocity and acceleration during the tertiary creep period has been identified, which give different values of α and A following the Voight model (Fig. 1c); (3) an outstanding dilation against a very short displacement appears in stage I, where the α value is small, on the contrary, the dilation becomes much less evident against a large displacement and the corresponding α-value is much greater (Figs. 1c-1d); (4) similar results were obtained on silica sand in normal-stress controlled tests and sample with complex dilatancy showed complex kinematic behavior.

(4) Publications of research findings

Chang, C.R., Wang, G.H. (Jun 2020): The power-law singularity and its application for failure forecast of rainfall-induced landslides, AGU-JpGU Joint Meeting 2020, Online, H-DS09

Chang, C.R., Wang, G.H. (Oct 2020): Creep behavior of clayey soils in ring shear tests and elevating the precision of time prediction of slope failure, サイエンス倶楽部デイ 2020, Kyoto Univ., Online

Chang, C.R., Wang, G.H. (Feb, 2021): Nonlinear behaviors strongly modulated by precursor shear deformation: mechanisms and implications for time prediction of landslides, 2020 DPRI Annual Meeting, Kyoto Univ., D104

Chang, C.R., Wang, G.H. Creep of clayey soil induced by elevated pore-water pressure: implication for predicting the time of failure of rainfall-triggered landslides, paper submitted to Engineering Geology.

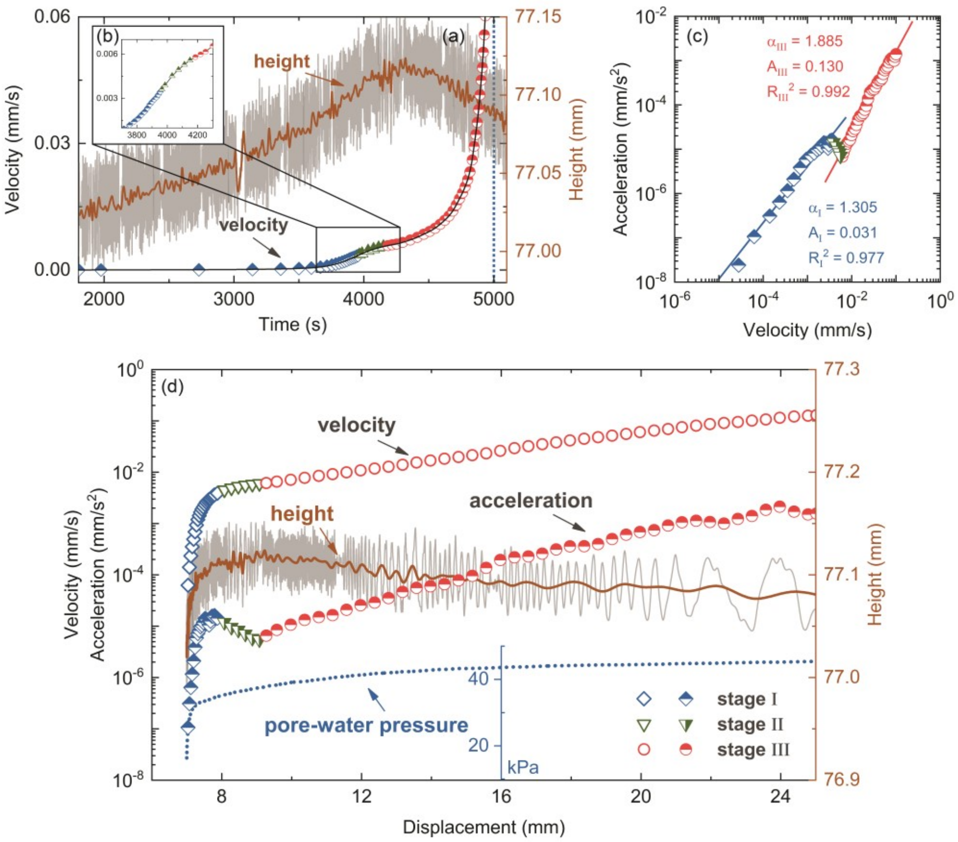

Figure 1. The kinematic features and height variation of the Kinokawa sample in a pore-water pressure controlled test