Development of a Near Real-Time Early Warning System on Landslides Triggered by Heavy Rainfall along the Mekong River, Cambodia

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Abstract

Situated in the southwestern part of the Indochina peninsula and roughly square in shape, Cambodia is covered by wet humid climate, and dominant features: Tonle Sap and the Mekong River which traverses the country from north to south. The whole country is wet, the soil is fertile, and the rain forest is thickly green. Simultaneously, this homeland is very susceptible to natural disasters, especially landsliding. After a continuously heavy rain over night, downstream areas were flooded, inducing various types of mass movement in the upslope areas. The Mekong lowland, in particular the area along the Mekong River bank holds the highest population, economically sounds and has remarkable development progress. Catastrophic landslides have frequently occurred and attacked the down-slope area under heavy rainstorm condition. Every time, roads have been cut, houses were damaged, and claimed lives of dozens of people.

Obviously, landslides triggered by heavy rainfall along the Mekong River are now major and complex issue that significantly interrupts the development of Cambodia. It is well and widely recognized throughout the nation, but mechanism, prediction and assessment of those phenomena in Cambodia are poorly understood, particularly, (1) shallow landslide triggering mechanism in the tropical soils is not yet uncovered; (2) mechanism of precursor signs of landslides, i.e., accelerating displacement is not yet solved; (3) even though a certain number of networked rain gauges get operational near real-time, optimization of water penetration coefficients in each district should be combined with various factors. Therefore, this study aims at studying mechanism of landslides in the tropical soils by using ring shear apparatus invented by DPRI, and the Tertiary Creep mechanism in help to the early warning on rainfall–induced landslides and apply Japanese Soil-Water Index to south-eastern Asia countries for landslide early warning.

The expected outcomes of this study are (1) to formulate the empirical equation of tropical soil characteristics applied in the south-east Asia countries, (2) to understand the failure mechanism of the tropical soils, which significantly influences the formula variables, (4) to propose a numerical model using DEM (Discrete Element Method) or FEM (Finite Element Method) validated in ASEAN regions if possible and (4) to predict and/or warn the rain-induced landslides through the application of TRMM and Tank Model.

Keywords: ring shear apparatus, soil-water index, Tertiary creep, tank model, TRMM.

Doctoral research plan

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Contents

Introduction

Location: Southwestern part of the Indochina peninsula.
Boundary: Thailand & Laos on the North, Vietnam on the East & Southeast, and Gulf of Thailand & Thailand on the West & Southwest.
Dominant features: Tonlé Sap and the Mekong River traversing from North to South.

Problem setting

1) Shallow landslide triggering mechanism in the tropical soils is not yet uncovered.
2) Mechanism of precursor signs of landslides, i.e., accelerating displacement is not yet solved.
3) Even though a certain number of networked rain gauges get operational near real-time, optimization of water penetration coefficients in each district should be combined with various factors.

Objectives

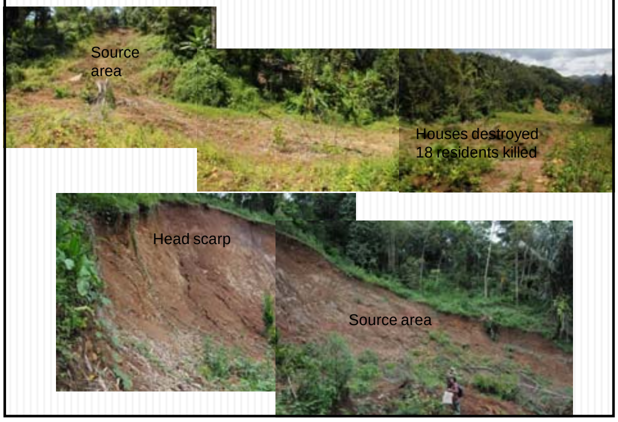
1. To study mechanism of landslides in the *tropical soils* using ring shear apparatus invented by DPRI.
2. To study the Tertiary Creep mechanism in help to the early warning on *rainfall-induced landslides*.
3. To apply Japanese Soil-Water Index to *south-eastern Asia countries* for landslide early warning.

Methodology

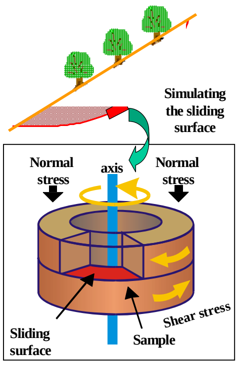
The study mechanism of landslides in the tropical soils by ring shear apparatus in DPRI, Kyoto University

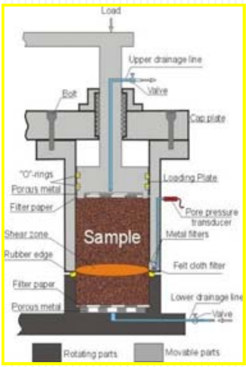
Examples of landslides in Indonesia

Nov. 2008 Campaka landslide, Indonesia

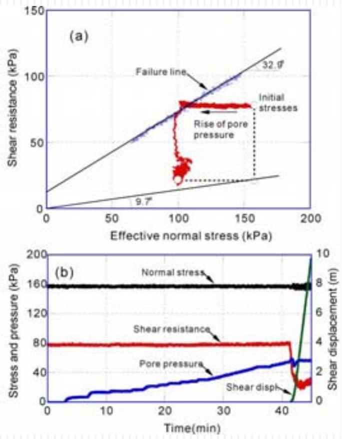


Ring-shear tests for reproduction of landslide movement





undrained shear box



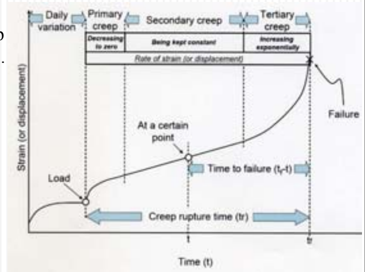
Results of tests to simulate the initiation of the Minamata landslide (BD = 0.86) (after Sassa et al. 2004a).

Methodology

The study the Tertiary Creep mechanism in help to the early warning on rainfall-induced landslides

The concept of creep in soils

- In many landslides, the failures are preceded by accelerated trend of displacement. It is associated with crack growth, soil particles rearrangement and shear surface evolution.
- A slope failure seldom occurs without any creep deformation and fissures.
- Creep deformation is expressed as a time-dependent deformation, or deformation under constant stress and temperature.



Literature reviews

- In landslide filed, failure-time prediction method of landslide have been widely developed by many researchers: Saito and Uezawa (1960, 1966) as a start, Saito (1968), Kawamura (1984), Fukuzono (1978, 1982, 1985), Voight (1988, 1989), Azimi (1988), Hayashi et al. (1988), etc.
- As mentioned above, only the two methods established by Saito and Uezawa (1960, 1966), and Fukozono (1985) based on the creep rupture theory are more precise in estimating appropriate failure time of a slope being previously monitored by creep deformation.

Time prediction of landslides

- 1965 – Saito (on Secondary and Tertiary creep) : proposed a method for predicting the time of failure of a slope based on graphical analysis of extensometer monitoring data.
- 1985 – Fukuzono (on Tertiary creep):

found log of acceleration is proportional to the log of velocity of surface displacement.

$$d^2x/dt^2=A(dx/dt)^{\alpha}$$

where x is surface displacement, t is time, and A and α are constants.

- Yet, higher accuracy needs to be improved. And, the mechanism of creep deformation is still not yet well-understood at the present.

Literature reviews (cont.)

- Recently, Minamitani (2007), Ekaterina, and Chiyonobu conducted research on the Tertiary Creep Mechanism by increasing constant pore-water pressure and shear-stress development to understand the story behind the empirical relationship found by senior researcher Fukozono.
- The most recent research by Taichi(2007) on mechanism of Tertiary Creep deformation for landslide failure time prediction. The study focused on Tropical soil characteristics in South-east Asia countries on Tertiary Creep mechanism in particular to displacement and time variation with constant σ,τ and u. However, the number of data are not enough for appropriate failure time prediction of landslide.

Experiment plan

To study mechanism of landslides in *tropical soils* by ring shear apparatus (invented by DPRI) based on Tertiary Creep deformation theory in help to the early warning on *rainfall–induced landslides*, pore-water pressure control tests are to be undergone under combined conditions of particular normal stress and shear stress with pore-water pressure change to simulate the potential sliding surface condition in the heavy rainfall.

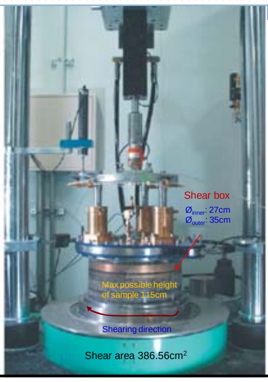
Thus, the originality is the first pore water pressure control test by ring shear apparatus to simulate heavy rainfall induced landslides. Especially, nobody did those tests by applying cyclic or actual groundwater change pattern to the soils/sands.

Ring shear apparatus DPRI-Ver. 7

(Undrained testing and pore pressure monitoring)

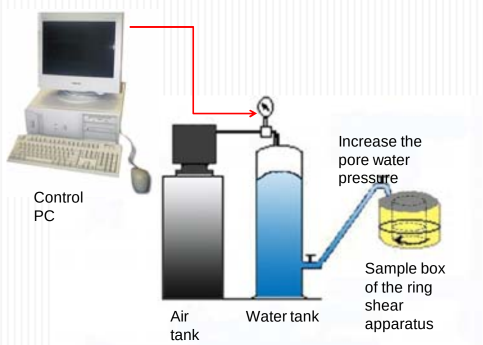
Ring shear tests with silica sands #8 & masa sands and actual landslide' sliding surface soils (brought from Indonesia, Cambodia and Japan) on Tertiary creep by applying actual ground water pressure pattern.

Numerical simulation of creeping to develop most appropriate method for landslide early warning.



- Technical parameters of DPRI-7:
- Ratio of max. height/width: 2.88
- Max. normal stress: 500kPa
- Max. shear speed: 300cm/s (adapted to shallow landslides)

System for back-pressure control



Planned experimental conditions

A) Testing materials:
 (1) mixture of silica sands #8 (mean grain size of SS8 ≈ 0.06mm) with bentonite clay
 (2) masa sands (weathered granite sands)
 (3) tropical soils from landslide sites

B) Slope inclination (Θ):
 (1) 30° (2) 25° (3) 20° (4) 15°

C) Over consolidation ratio OCR:
 (1) 1.0 (2) 4.0 (3) 2.0

Planned experimental conditions (cont.)

D) σ (normal stress)= (1)100kPa
 (2) 50kPa for additional test

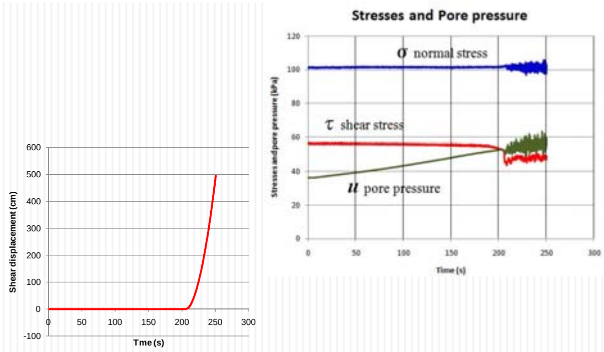
E) du/dt= (1) constant
 (2) simulating to real groundwater record
 (3) cyclic

F) Initial B_D=Δu/Δσ (saturation degree by Sassa,1988):
 (1) BD >0.95
 (2) BD <0.95

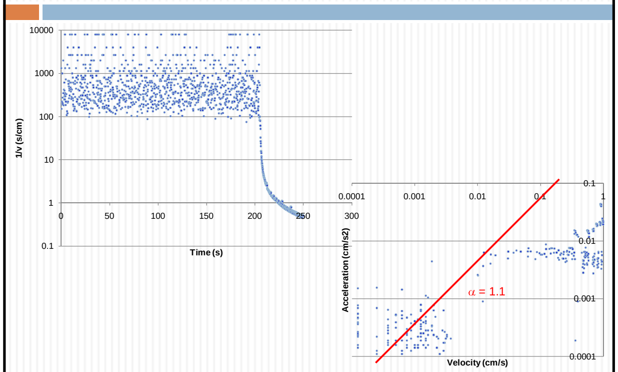
Test conditions

- OCR = 1.0 (normally consolidated)
- CO_2 circulation: 30 minutes
- Pore water: tap water (not de - aired water), circulation for 1 overnight
- B_D = 0.66 (normal stress = 50 → 100 kPa)
- Normal stress (σ) = 100 kPa
- Shear stress (τ) = 54 kPa
- Slope inclination (Θ)= ($\tan^{-1}$ (τ/σ)) = 30°
- u_0 = 15 kPa
- du/dt = 1 kPa/s.

Test results, du/dt=1kPa/s



Test results, du/dt=1kPa/s



Expected Outcome

- Formulate the empirical equation of tropical soil characteristics applied in the south-east Asia countries.
- Understand the failure mechanism of the tropical soils, which significantly influences the formula variables.
- If possible, propose a numerical model using DEM (Discrete Element Method) or FEM (Finite Element Method) validated in ASEAN regions.
- Predict and/or warn the rain-induced landslides through the application of TRMM and Tank Model.

Thank you for your attention!!!