Field behavior of a silty sandy soil during successive rainfall events

The University of Tokyo — Carlos Bacca Bautista and Taro Uchimura
Chuo Kaihatsu Corporation — Wang Lin
Public Work Research Institute — Taro Uchida and Yoske Ito

1. Introduction

Landslides in residual soils occur frequently in many places around the world after rainfall periods causing many deaths and material losses. Regardless of the efforts that have been made to improve slope safety, many issues related with this kind of phenomena still have not been fully understood.

It has been observed that many landslides, in weathered soils slopes, present shallow slip surfaces above the water level and under unsaturated conditions. In situ investigation related to the slope response due to rainfall and water infiltration, has indicated that suction is reduced by infiltration of water which can be a destabilizing factor. Although some studies have described the effect of intensive rainfall in residual soils under partially saturated conditions (Yoshida 1991), few of them have studied about the effect of consecutive repetitive rainfall events in the accumulation of deformations, under constant stresses and its effect in the safety factor. Moreover, few researches have been concentrated to study this problem in term of critical deformations under constant shear stress as occur in real cases(Brand 1981).

The present study attempts to understand the rainfall effect into shallow part of slopes considering the influence of successive rainfall events into the soil water content and the accumulation of deformations after successive rainfall events. In order to study this phenomenon, water content sensors and electronic inclinometers have been placed in a weathered slope at Kobe city, Japan, in order to monitor these two parameters. According to preliminary field information, it has been identified that after every rainfall event considerably increments in the water content and displacements have been found in special after successive rainfall periods.

However, due to the absence of a failure condition in the slope, critical parameters cannot be defined. Therefore, Triaxial test under anisotropic constant stress states and suction measurement during the wetting process are being carried out in order to understand the failure mechanics during the infiltration process.

2. Soil characterization

According to the in situ visual characterization, the shallow material at slope in Kobe city corresponds to discomposed granite. The regional geology is composed by plutonic rock especially granite type. The residual soil is basically identified as light brown, silty clay sand. The particle-size distribution of the material is shown in the Fig. 1.

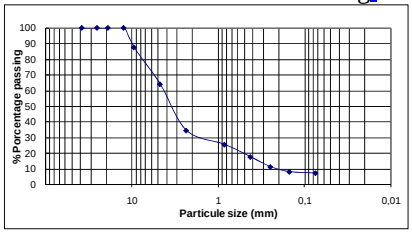

Fig 1. Grain size distribution

3. Instrumentation system

The distribution of instrumentation within slope is shown in the Fig. 2. The chosen places were located around previous shallow landslides in the study area. Fig.2 shows the chosen instrumentation points which are named with letters A, B, C ,D. For every instrumented point, water content sensors and electronic inclinometers were installed.

The water sensors were pushed inside the soil at depth of 30 cm after open a small hole into the soil. The inclinometers sensors were located inside the internal collector unit which was previously tied to a metal bar sank into the soil at 40 cm of depth (See Fig. 3).

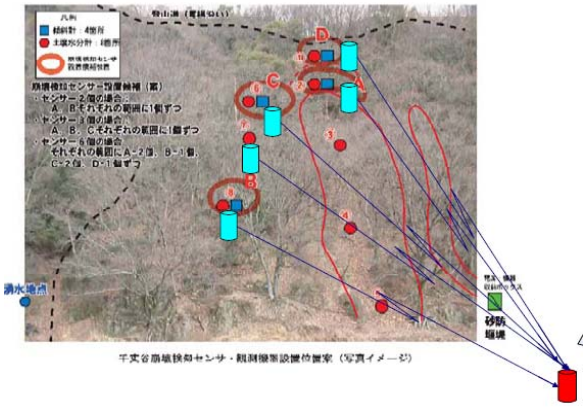

Fig 2. Localization of water content sensors and inclinometers .The red points correspond to water content sensor while the blue square corresponds to inclinometers.

The electronic inclinometer used in this study has the possibility to measure the angle of rotation for three axes, between a range of -30° and 30°. The X axis corresponds to the inclination on the slope direction and the negative values measured for this device in the X axis will correspond to the inclination at the forward slope direction.

The schematic diagram about the instrumentation is shown in the Fig. 3. To transfer the information between measuring points and the central control base, each sensor unit was connected by wireless communication system to a laptop located in the bottom part of the slope.

Into this computer a cell phone antenna was placed with the aim of transfer the information to the central collector located at an office in Tokyo. This wireless system was developed by the University of Tokyo and Chuo Kaihatsu Corporation as a research project with the goal to obtain easily real-time date at instrumented slopes

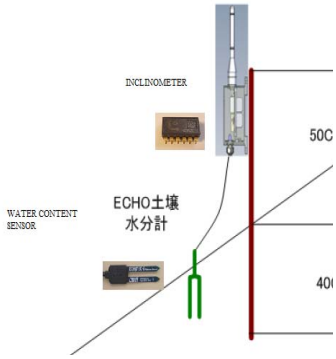

Fig 3. General installation of water sensors and inclinometers.

Key word: Unsaturated soils and monitoring systems
Contact address: The University of Tokyo 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, JAPAN

Partially field monitoring result

The analyzed information in this paper corresponds to the period from April 17 to June 22; 2008. The information was recorded every 10 minutes. Fig. 4 shows the variation of water content for every instrumented point. By examining this information the following observations are made:

- The response of the water content into the soil is evident after every rainfall event for all the instrumented points.
- The increment of water content is different for every point. The maximum increments in the water content value were identified for points B and D, where the average increment was approximately 40%. Points A and C the average increment was about 20%. These differences could be attributed at changes in the landform which could allow the accumulation of water.
- Once every rainfall was over, decrement of the water content is observed. This change will depend on the duration of the dry period.
- During the period between May 12 and June 5 2008 five successive rainfall events were registered. In this period an accumulation in the water content into the soil is observed despite of the consecutive

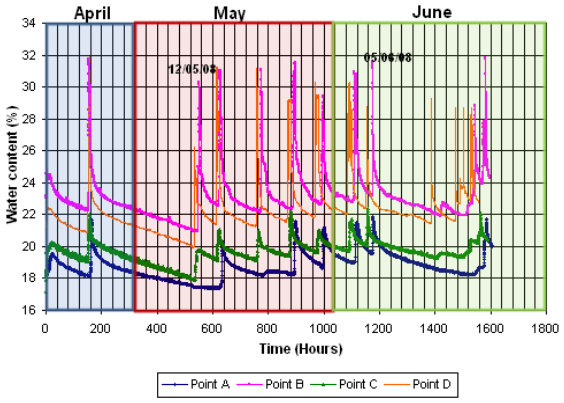

Fig. 4. Variations of the volumetric content into the soil from April 17 to June 23, 2008.

Fig. 5 shows the inclination variation in the slope and its relation to the water content for Point B. Due to the sensitivity of inclinometers, represented in the consecutive fluctuation of values; a wide line has been drawn in order to show the average trend. Additionally, to analyze the behavior after successive rainfall events, shadow rectangles on the graphs were placed.

By analyzing the inclination information the following observation are made:

- A small increment in the inclination value is identifying during every rainfall event.
- Despite of the sensibility of the sensors and the small inclinations measured, accumulations of displacements during the rainfall period for all the instrumented points were found. This increment is higher in the period between May 12 and June 5 2008, where five consecutive rainfall events occurred.
- During the instrumentation period, small deformations were observed. This means that no limit values were reached.

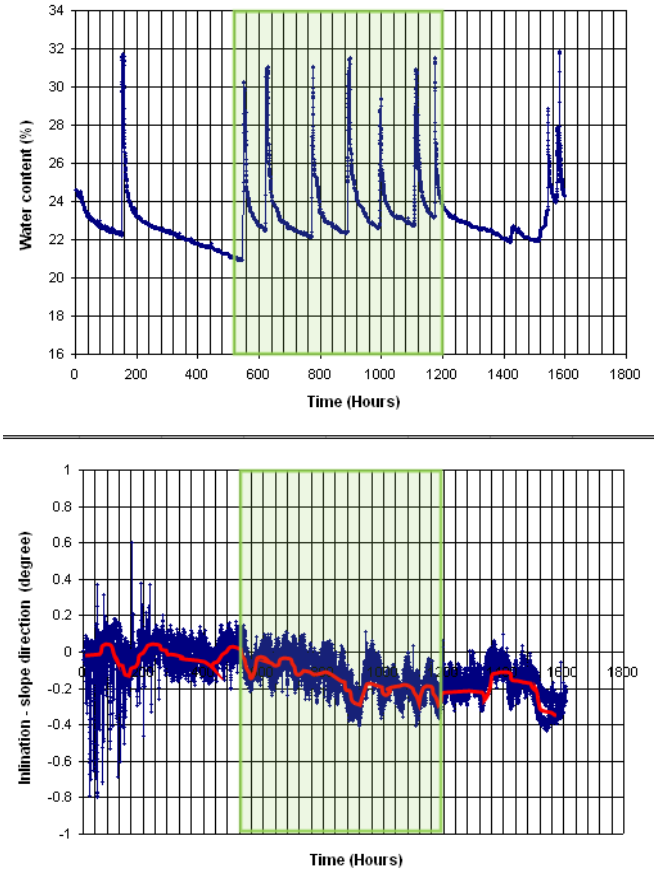

Fig. 5. Variation of the inclination in the slope and its relation to water content into the soil.

5. Conclusions

The partial results of this investigation show that:

- The response of the water content into the soil after every rainfall is evident event for all the instrumented points
- After consecutive rainfall events an accumulation of deformations occurred into the soil mass.
- During the present instrumentation period, small changes in the inclination for each control point have occurred. However, it is important to study the behavior of these types of soils under different wetting and drying condition in order to identify the shallow mechanics of failure, common in this kind of soils. To study more in detail this process, some triaxial test under unsaturated conditions are being carried out.

References

Yoshida Y. (1991). Rain induced slope failures caused by reduction in the soil strength. Soil and Foundations Vol.31, No 4, pp 187-193.

Dai Fuchu. (1999) Analysis of rainstorm-induced slide debris flows on natural terrain of Lantau Island, Hong Kong. Elseiver Engineering Geology 51 (1999) 279-290.

R.H.Chen and S.C.Yang. (2000). Study on debris-flow triggered by pore water pressure.

Yoshida Y., Kuwano J. and Kuwano R. (1991). Effects of Saturation on Shear Strength of Soil. Soil and Foundation, Vol. 31, No. 1, pp. 181-186

Brand, E.W.(1981) Some toughts on rain-induced slope failures. Proc. 10th ICSMFE, 3, 373-376, Stockholm.

Key word: Unsaturated soils and monitoring systems
Contact address: The University of Tokyo 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, JAPAN