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Slopes behavior under integrated effect of Rainfall and Groundwater

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Introduction

Landslides become an infamous topic owing to the significant damage it makes to society and the economy. Many steps have been taken to minimize the damages caused by slope behavior in the recent past, especially by developing landslide early warning systems. These systems quite often provide a good prediction of spatial susceptibility. However, temporal predictability remains a problem since the lack of a more detailed hydrological process. Without debate, rainfall is one of the key external factors which causes a reduction in soil suction and soil strength and consequently triggers shallow landslides. Nevertheless, the effect of pre-existing groundwater table and its surcharge during a rainfall event is rarely studied.

Pre-existing groundwater conditions may occur on the soil-bedrock/impermeable interface due to the antecedent rainfall events or aquifers. The difficulty of contemplating the effect of pre-existing groundwater conditions directed to consider the rainfall as the reference parameter during landslide early warning. This might result in false predictions and can cause unexpected damage. The studies conducted by Marino et al (2021) showed the importance of initial conditions controlled by a perched aquifer in landslide simulation using field monitoring and numerical simulation. Therefore, the objective of this paper is to study the effect of the initial condition governed by pre-existing groundwater table on the soil-bedrock interface of a slope exposed to rainfall infiltration.

Methodology

Geotechnical centrifuge testing was employed to physically investigate the effect of pre-existing groundwater table of a slope exposed to rainfall infiltration. To examine the above objective a soil container was newly developed. This soil container can simultaneously reproduce the effect of groundwater table and rainfall. A schematic diagram of the soil container is shown in Fig 01.

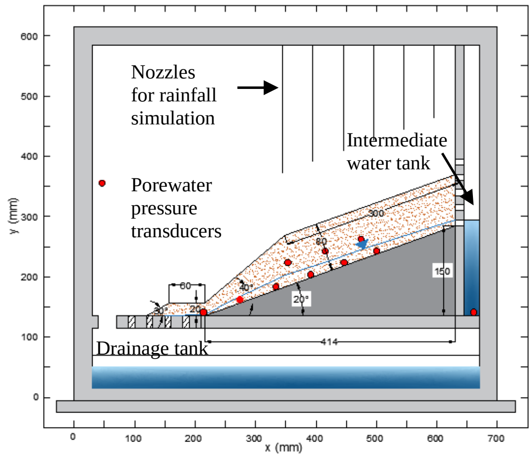

Fig. 1 Schematic diagram of the centrifuge container

Table 1. Material properties of Masado soil

Parameter and unit	Value
D_{60}, D_{30}, D_{10} (mm)	0.83, 0.32, 0.15
Particle density (G_s) (g/cm^3)	2.6
Max dry density (g/cm^3)	1.76
Optimum moisture content (%)	15.5
Sat. hydraulic conductivity (m/s)	4×10^{-5}
SWCC parameters (wetting) (α, n, m)	0.41,2.2,0.55
Friction angle $(\varphi°)$ and cohesion (kPa)	40, 0

Masado soil, well-graded silty sand was used in this experiment. Material parameters are given in Table 01. Air-dried soil was mixed with 10% of water and kept for 24 hours for homogenizing before using it. The slope was constructed by layer by layer wet-tamping method. Each layer was 20 mm and excess soil was scraped to obtain the geometry shown in Fig 01.

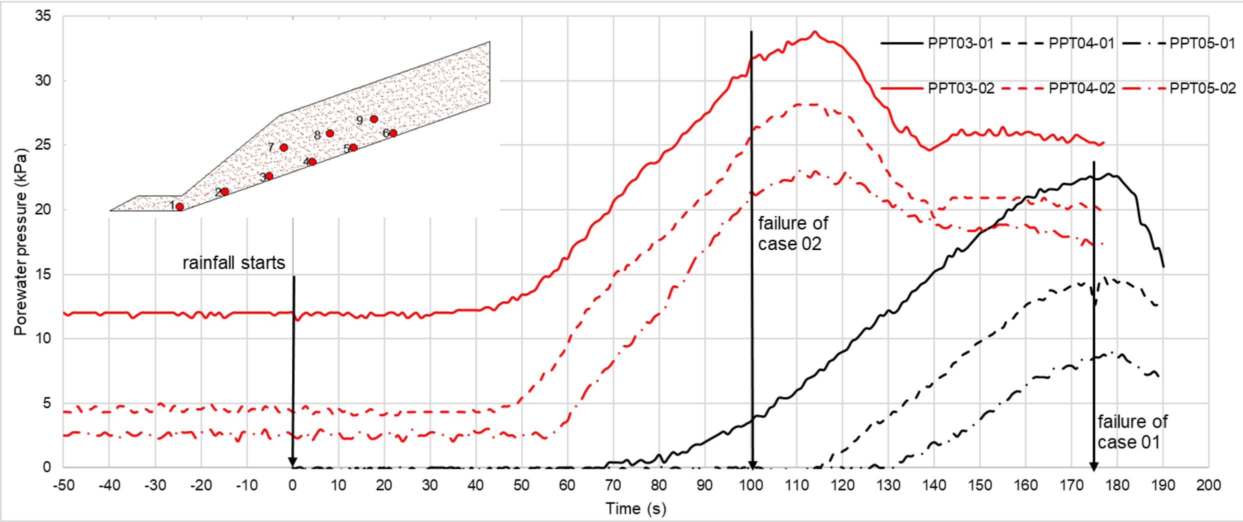

Fig. 2 Pore water pressure distribution of Case (i) and Case (ii)

During the slope construction pore water pressure transducers (PPTs) were buried to acquire pore water pressure distribution, and markers were placed in between the soil slope and transparent window to catch the displacements. Two cases were conducted in this experiment: Case (i) rainfall only and Case (ii) rainfall infiltration on a pre-existing groundwater table. In Case (ii) firstly, the groundwater table was simulated and tried to maintain the response of PPTs constant before applying rainfall. All the tests were conducted under 50*G* conditions in the centrifuge testing facility at Disaster Prevention Research Institute, Kyoto University.

Results and Conclusion

The porewater pressure distribution of Case (i) and case (ii) are illustrated in Fig. 2. According to this, failure in Case (ii) happened after around 100 s of the onset of the rainfall whereas failure in Case (i) took place around 175 s. In Case (i) development of excess water pressure was delayed since percolated rainfall took time to reach the soil-bedrock interface. However, in Case (ii) PPTs responded quickly. This can be because the distance for generating a vertical seepage path is lesser with the presence of pre-existing groundwater table. Therefore, the interaction between the groundwater table and rainfall created an increase in pore water pressure critically compared to Case (i). Even though this is a more complex observation, it clearly emphasizes initial hydrological condition is a vital parameter for the temporal prediction of landslides.

Acknowledgements

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