Centrifuge modelling of slopes subjected to intermittent rainfall infiltration conditions

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1. Introduction

Occurrences of slope failures subjected to rainfall conditions are greatly discussed and reported in the literature. Contribution of rainfall infiltration to the development of positive porewater pressure (PWP) and loss of matric suction have been studied extensively using physical modelling techniques such as centrifuge modelling, 1-*g* modelling and field instrumentation. However, centrifuge modelling has advantages such as replicating the stress levels and repeatability of tests. Therefore, many hypotheses are studied in centrifuge modelling in different conditions of slopes (Take et al 2004). By referring to the many case histories such as Dang et al 2019 it is observed that rainfall conditions mostly show an intermittent pattern. Nevertheless, it is found that not many studies have been conducted to study the intermittent rainfall infiltration conditions in coupled hydro-mechanical analysis. This abstract discusses the influence of intermittent rainfall conditions to slope failure through PWP development.

2. Experimental setup

2.1 Centrifuge facility

Disaster Prevention Research Institute (DPRI) 24g-tonne, 2.5 m radius geotechnical centrifuge at the Kyoto University was used for testing the slope models. For this study, rainfall was simulated using 18 air atomizing nozzles which uses water flow and air flow (Xu et. al 2021). The rigid box has internal dimensions of 600×300×140 mm. In this experiment, water was used as the pore fluid and the water tank is fixed to the rigid box. Ten porewater pressure transducers (PPT) are inserted during the construction of slope. Several markers are placed in between soil slope and Perspex window to catch soil deformations using image analysis techniques. The scaling factors relevant to the study are given in Table 1.

2.2 Slope material and construction

Masado soil, which is a commonly used in geotechnical application in Japan was used in these experiments. Basic properties of the Masado soil are presented in Table 2. A few trial tests were carried out previously and decided to adopt 1.5g/cm^3 as the dry density of soil. Prior to construct the slope, required amount of dry soil was mixed with respective water contents and kept in sealed bags to homogenize for 24 hours. After soil was compacted using wet-tamping method in layers of 20 mm thickness extra soil was removed to provide the required geometry (Fig. 1).

2.3 Testing program

To study how intermittent rainfall can impact the slope behavior, two tests were carried out so far. First test (Test A) was conducted using 25 mm/hr (prototype) continuous rainfall (Fig. 2) and second test (Test B) was conducted using 25 mm/hr (prototype) intermittent rainfall (Fig. 3) conditions. All tests were conducted at 50-*g*.

Table 1. Scale factors relevant to the current study

Parameter	**Model**	**Prototype**
Stress	1	1
Length	1/N	1
Time (diffusion)	1/N^2	1
Rainfall intensity	N	1
Suction	1	1
Hydraulic Conductivity	N	1

Table 2. Basic soil properties of Masado soil

Property	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)	1.02×10^{-5}

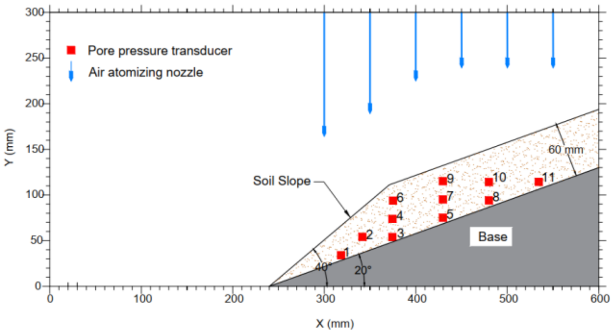

Fig. 1 Schematic diagram of centrifuge model

3. Results and Discussions

Shortly after the introduction of the rainfall onto the slopes, soil erosion was taken place in both tests. In addition to that, because of the geometry used in the test more surface runoff also observed. The PWP behavior of Test A and Test B are presented in Fig. 2 and Fig. 3 respectively for the PPT locations L-2 to L-8. Interestingly, both the failures have initiated at around 110 *s* (model time) irrespective of the rainfall patterns as illustrated in Fig. 2 and Fig. 3. According to Fig.2, the development of positive PWP attributed to the continuous rainfall and progression of wetting front is clearly shown whereas, Fig. 3 shows positive PWP developed a few seconds before the failure took place. Unfortunately, suction development during spinning-up and loss of suction with infiltration were not caught by the PPT used in these experiments.

With respect to the net rainfall time, Test B has received a 30 s of less rainfall than Test A. Therefore, cumulative rainfall experienced by two slopes are different in total. As far as the results are considered, failure happened in Test A is mainly due to positive PWP developed in the toe area and along the soil/base interface. In Test B, evolution of PWP profile during wetting and drying events might have affected to the shear strength behavior of soil. However, more in depth analysis is required to explain the possible reasons for these observations.

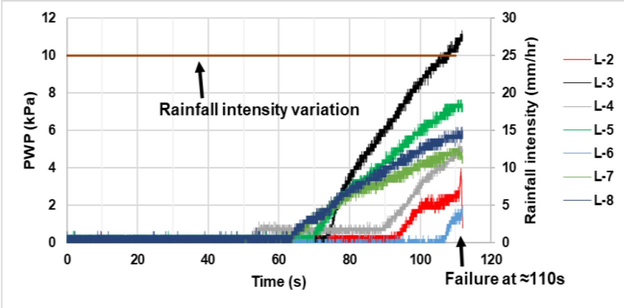

Fig. 2. PWP development of Test A

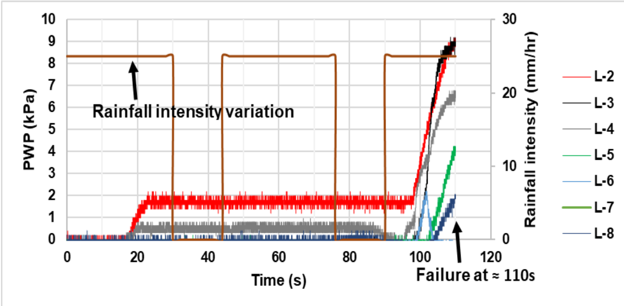

Fig. 3. PWP development of Test A

4. Conclusions

Results of centrifuge testing were presented in this paper to discuss the behavior of slopes respond to intermittent rainfall conditions. The results show that there is a significant effect on intermittent rainfall conditions on slope behavior. Together these results provide important insights into the vulnerability of slopes subjects to not only continuous rainfall but also intermittent rainfall conditions.

References

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