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EXPERIMENTAL STUDY ON THE INFLUENCE OF RAINFALL INFILTRATION AND GROUNDWATER SEEPAGE ON STABILITY OF HILLSLOPES

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1. Introduction

Most of slope failures have been associated with the infiltration of rainfall and the raising of groundwater water level in a hillslope. When the groundwater flows within a slope, the water is sometimes to seep out on the slope surface in the area near the toe. In this current research we focus on the experimental study on the influence of infiltration of rainfall and the effect of groundwater seepage on the initiation and mechanism of hillslope failures. The study also includes the detailed observation of the changes in pore-water pressure and moisture *content to understand the failure initiation and mechanism.*

2. Properties of soil

In this experiment, river sand was used as soil sample for slope model. Soil *particle varies from fine sand to coarse sand with little fines and the values of* D_{10}, D_{30} and D_{60} are 0.157, 0.369 and 0.7286 mm respectively. The unit weight of soil particle and the saturated hydraulic conductivity of the soil are 2.69 kg/cm^3 and 0.029 cm/s, respectively. Under direct shear and uniaxial tests, soil sample shows a maximum cohesion of 0.01028 KPa at saturation of 15.26 % with the internal friction angle of 50 degrees. The variation of cohesion with degree of saturation is given in Fig. 1.

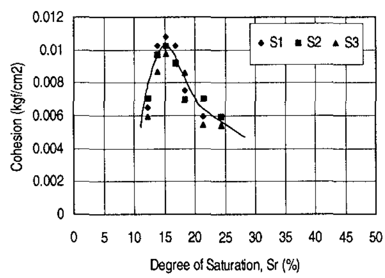

Fig.1. Variation of cohesion with saturation.

3. Experimental apparatuses and program

The one meter high sandy soil slope was constructed in a large acrylic-sided tank which was facilitated with observation window for pressure and deformation, and with gravel tank connected to an external constant head system. The tank was instrumented with moisture probes (ADR), pressure transducers and manometer standpipes. The slope model angle of 45 degree was chosen in all experiments. A rainfall simulator was set up above the landslide tank when the effect of rainfall infiltration was considered. The simulator was set to give a rainfall intensity of 100 mm/hr. The outline of the landslide tank and its instrumentation is shown in Fig. 2. The slope instability was induced by considering four different conditions of raising the groundwater level as summarized together with the respective slope parameters in Table 1. Except in experiment 4, a water level of 20 cm was initially introduced across the slope base from the constant head tank.

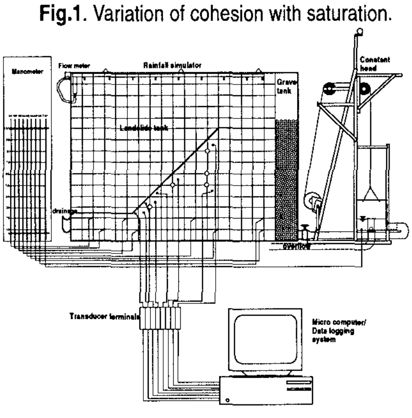

Fig. 2. Overview of instrumented landslide tank

Table 1. Slope Parameters

Exp. No.	Exp. Condition	Constant head tank	Rain	Initial moisture content	Dry Density, ρ_d(gr/cm^3)	Void ratio, e	Initial S_r (%)
1	Slow raising	Yes	Yes	0.071	1.431	0.879	15.41
2	Slow raising	Yes	No	0.074	1.434	0.875	15.45
3	Quick raising	Yes	No	0.071	1.409	0.909	15.19
4	Slow raising	No	Yes	0.081	1.429	0.882	16.09

4. Experimental results

4.1.Overall failure process.

Three dimensional nature of failure process in each experiments is schematically shown in Fig. 3. The overall failure process was preceded by saturation of the slope toe. In experiments 1 and 2, the failures commenced by cracking and subsequent shallow failures from the toe area progressively upwards when the seepage face was *formed in every stage of raising the groundwater level. Manometer readings show that* the seepage failure generally occurred when the groundwater reached a steady state condition. In contrast, in experiments 3 and 4, the slope

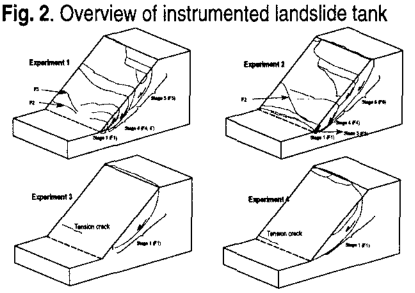

Fig. 3. Overall failure process in each experiments.

Keywords : *rainfall infiltration, groundwater seepage, seepage forces, hillslope stability, failure initiation*
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failed suddenly after cracking was developed at the toe area. Close examination on the photograph record indicates that the development of unstable area at the toe is associated with the formation of seepage face. This evident suggests that the seepage force was acting on the saturated area of the slope to introduce localized unstable area which would then affect the overall stability of the slope.

4.2. Failure modes

Retrogressive non-circular sliding and circular sliding were the failure modes observed in the experiments. Among other factors, the mechanism of introducing the raising of groundwater level obviously determined the mode of failure. Except in experiment 4, the gradual raising of groundwater level will lead to retrogressive failure, while sudden raising can associated with single circular sliding.

4.3. Pore pressure and moisture content at failure

Figures 4 to 7 show the increasing trend of pore water pressures throughout the experiments with a significant transient increase or decrease at main failure. The records at failure indicate that very significant excess pore water pressures were generated during (but not preceding) failure. However, when toe failure took place insignificant increase of pressure was observed. This demonstrates that the occurrence of toe failure results from saturation of toe slope by which the strength of soil becomes zero. The records of moisture content show an increasing trend with time throughout experiments (Fig. 8 and 9). The records also reconfirm that the most of toe failures occurred at saturation. In experiment 4, the records of pore water pressure and moisture content (Fig. 7) show that the slope body had experienced saturation prior to main failure when wetting front touched the unsaturated boundary of the slope base. The failure itself was observed to take place at the same time as the toe cracking developed and grew larger when the toe was saturated (Fig. 9).

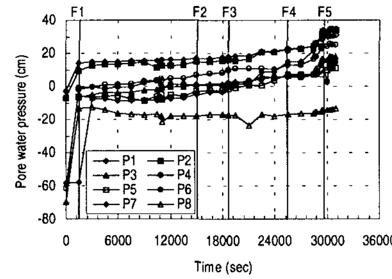

Fig. 4. Variation of pore water pressure with time (experiment 1).

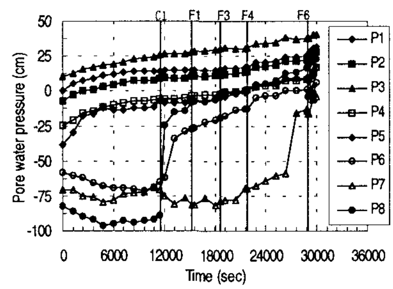

Fig. 5. Variation of pore water pressure with time (experiment 2).

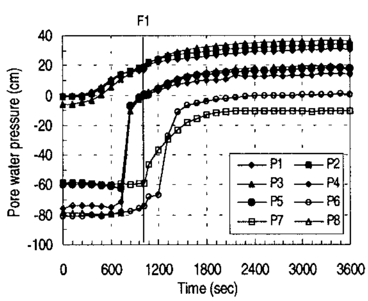

Fig. 6. Variation of pore water pressure with time (experiment 3)

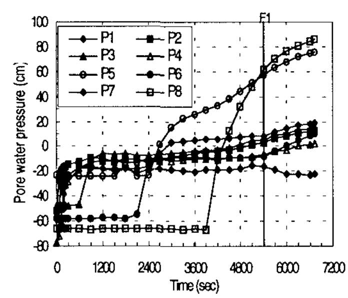

Fig. 7. Variation of pore water pressure with time (experiment 4).

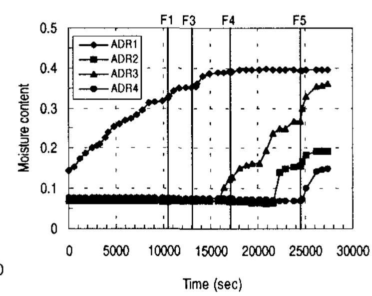

Fig. 8. Variation of moisture content with time (experiment 2).

6. Conclusion

From the foregoing experimental study, the following conclusion may be drawn:

(1) The formation of seepage face on the toe area contributes to the development of highly unstable area around the toe which will disturb the overall stability of the slope owing to the existence of seepage forces acting upon the slope.

(2) The rainfall infiltration will accelerate the initiation of failure on hillslope. The saturation of hillslope by rainfall infiltration will significantly reduce the stability of hillslope.

(3) The combination of moisture content and pressure measurements leads to a better understanding on failure prediction and initiation.

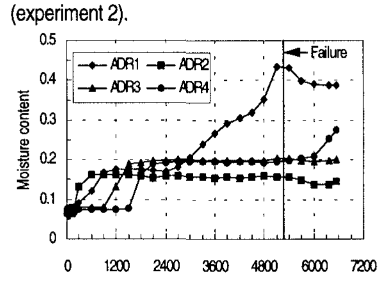

Fig. 9. Variation of moisture content with time (experiment 4).

Reference

Nishigaki, M., Adrin Tohari, and Mitsuru Komatsu (1996). Stress and Seepage Vector System on Stability Analysis of Hillslopes. Proc. Int. Conf. On Water, Environment and Disaster Prevention (ICWEDP'96), Zhengzhou, China.