Effects of bedrock-flow on related to shallow landslide initiation through a large flume experiment

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1. Introduction

Several field investigations have attempted to record the shallow ground-water conditions that initiate debris flows by landslide(Harp et al.,1990; Johnson and Sitar 1990; Montgomery et al. 1990; Iverson et al., 1997). Iverson et al., (1997) described hydrologic response patterns through mechanical analyses of slope stability and debris flow mobilization that differ from conventional ideas regarding slope instability. However, the effect of shallow groundwater flow on shallow landslide initiation have not been fully understood(Uchida et al., 2001), and there have a few study to obtain high-resolution hydrological data for the relatively infrequent hydrologic conditions that trigger a failure on slope(Reid et al., 1997).

Reid et al., (1997) proved effect of groundwater by using water injection method through flume experiment. They performed that experiment using on 31° of flume slope, groundwater inflow and moderate rainfall intensity, and they explained on the effect of groundwater. This is, however, shortage to explain on effects of groundwater by change of hydraulic gradient that occurring shallow landslide initiation. Our experiments focused on high-resolution hydrological process monitoring in response to groundwater under different hydraulic gradient (*i*), which were occurring shallow landslide during 2 kinds of water injection experiments, and comparison of Reid's experiment(1997) and our experiments.

2. Research Method

We have installed subsurface monitoring instruments and collected data in detail, which including of total head data, ground-water data, discharge data and water pressure data according to change of hydraulic gradient, in the National Research Institute for Earth Science and Disaster Prevention (NIED), Japan. All experiments used relatively homogeneous, isotropic granular sand, which were placed behind the retaining wall using a front end loader and hand shovels. The large steel flume (Experiment I : 7m long, 2m high, 0.6m deep and slope 20 degree. Experiment II : 7m long, 2m high, 0.6m deep and slope 30 degree), and artificial rainfall simulator were used in the landslide experiment as shown in Figure 1. One wall of the entire flume was made of clearly reinforced glass to enable direct observation of soil deformation. We detected this experiments using a digital video camera and then analyzed it in laboratory such as shape of landslide or/and timing of failure.

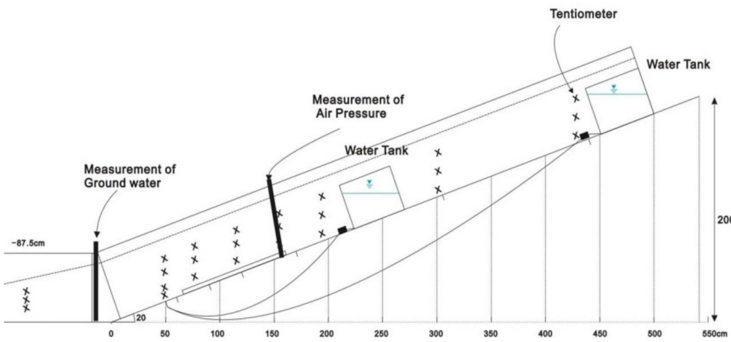

Figure 1 Experiment diagram of change of hydraulic gradient using large flume in NIED.

To obtain data changed by different hydraulic gradient, we have also installed water tank connected with a hose at the flume bed and we calculated hydraulic gradient, i

$$i = \frac{\Delta h}{l} \qquad (1)$$

where, Δh is height from soil surface to water surface in water tank, l is a soil depth.

3. Results

3.1 Water Injection Experiment I

Figure 2 depicts the hydrologic response to water applied exclusively by subsurface inflow. Reid et at., (1997) mentioned that when they performed groundwater inflow experiment, he create a nearly slope-parallel water table with negligible ground-water exfiltration at the slope toe and tensiometers measured pressure head were a negative before experiment, indicating that soil was unsaturated, but our experiment was a contrast to their experiments. During injection of water (i= 2 and i= 4) at 50mm/h rainfall intensity and injection of water (i=7) at 80mm/h rainfall intensity to detect effects of hydraulic gradient, the groundwater table that flows along the flume bed was not paralleled at lower part of this flume. Initially, most of the tensiometers measured negative pressure, but before water injection all of tensiometer measured positive pressure, indicating that the soil was already saturated. During water injection experiments, we obtained rapidly changing pressure response to change of hydraulic gradients. The tensiometer-40cm deep on downslope near the water injection responded to upward direction very high and tensiometer-25cm deep, tensiometer-10cm deep, respectively, in experiment I (i=2 and i=4). The tensiometers located upward on flume also responded to water injection, but the responded pressure head was a small more than tensiometer-50cm. In here, response of all tensiometer installed deepest has the highest pressure head values, that is because of seepage force(Iverson et al., 1997) by change of hydraulic gradient (Figure 2, Left) and failure occurred and width of failure was increased according to change of i.

3.2 Comparison of Water Injection Experiment I

In Experiment II (i=7), we obtained same results in response to water injection like experiment I, except groundwater level (Figure 2, Right). Initial pressure head was a large near injection hole more than experiment I and all of tensiometers installed upward direction on flume was also same(Figure 2,Right). That is, during water injection, rapidly increasing groundwater affected to upward direction and also failure occurred in experiment II.

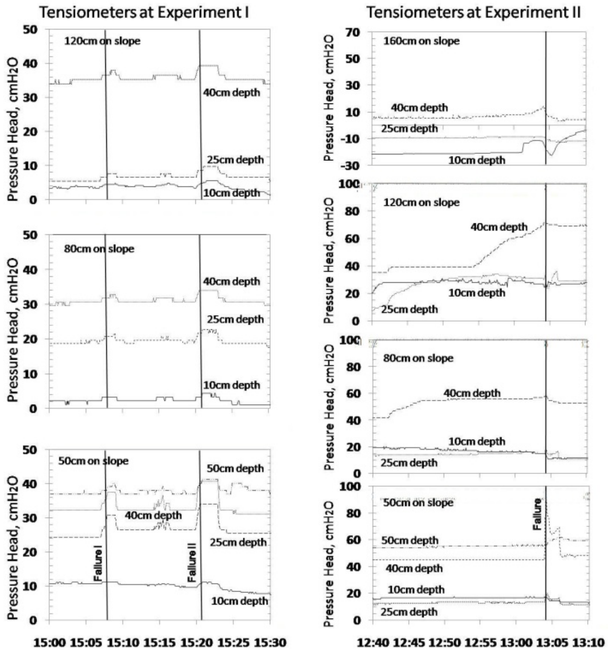

Figure 2 Hydrologic response during experiments (Water Injection (Left : i=2, i=4; slope 20°) and (Right : i=7; slope 30°))

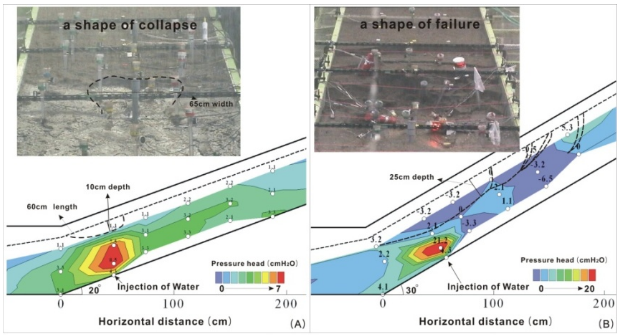

Figure 3 Shapes of landslide and change of pressure head during injection of water experiments (Left : i=4; slope 20°) and (Right : i=7; slope 30°)

4. Discussion

In our experiments, positive pressure head increased dramatically, indicating that soil was saturated. It is explain that change of groundwater level was sensitively responded to change of hydraulic gradient(Figure 2). And then because of these effect of transiently increased groundwater, failure was occurred(Figure 3). In here, change of hydraulic gradient(i) that have more high values effected groundwater level and occurred failure, but groundwater was not paralleled on slope in contrast to Reid et al.,(1997). We also obtained two kinds of shallow landslide mobilization, which one was shape of collapse and the other failure was shape of failure by transiently increasing groundwater related to hydraulic gradient effect that occurring landslide initiation (Figure 3).

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