Role of non-plastic fines on the initiation and movement of rainfall induced landslides in laboratory flume tests

○Chao HUANG, Gonghui WANG

Introduction

Landslides affect the flanks of mountainous and volcanic edifices on earth, which locally constitute an important natural hazard on earth. Non-plastic fines exit in the landslide in abundance including original slope and landslide deposits. For original slope, some landslides tend to occur on the material rich in fine soil particles like granitic soil, such as the 2014 Hiroshima landslides triggered by rainstorm, Japan. Non-plastic fines were also found in loess landslide, debris avalanche deposits and tailings dam landslides, which were characterized by rapid movement and long runout distance. The 2008 Wenchuan earthquake triggered numerous landslides and resulted in the formation of many landslide dams, which composed of unconsolidated fine debris. Recent studies on these landslides and dams revealed that secondary landsliding phenomena had been widely triggered on these landslide deposits, and the initiation and movement of these landslides are greatly related to the involvement of fine materials. However, most understandings on the effects of non-plastic fines are based on element testing of small specimens under idealized conditions, and had been rarely verified by physical modeling experiments. Hence, this study aims at examining the effect of non-plastic fines on the initiation and movement of rainfall-induced landslides in flume tests.

Material and Method

Samples for the tests are mixture of silica sand No. 7 with differing contents (0%, 10%, 20%, 30%, 40% and 50%) of silica powder by weight. Before setting, the mixtures were prepared to have an initial water content 10%. A flume as descripted in Figs. 1 and 2 was employed, which has transparent sides and is 180 cm long, 24 cm wide, and 20 cm high. During test, the flume was sloped to 20°. Pore-water pressure and tilting transducers are installed at within the soil model to monitor the water pressure and inclination. Cameras were used to monitor the test process from one side of the flume and also from the toe part.

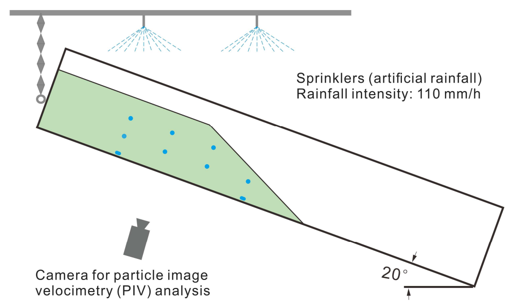

Fig. 1 Flume tests for rainfall-induced landslide

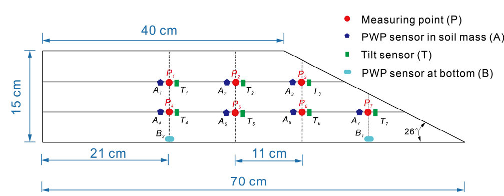

Fig. 2 Landslide model and setup of sensors

Results

In general, it took 30 min for the slope wetting, and another 20 min for failure. In the tests on silica 7 and its mixtures with 10%, 20%, 50% of silica powder, retrogressive sliding occurred in each test. However, in the tests on the mixture of silica 7 with 30%, 40% of silica powder, fluidized sliding occurred.

Fig. 3 shows the different periods of individual slide episode identified by tilting sensors in flume tests. It is noted that the tests on samples with fines content (FC) being 30 and 40% showed typical transitional sliding. It is seen from Fig. 3 that the lasting time for each individual sliding decreases with increase of FC until reaching 30% and 40%, then increase with further increase of FC.

Fig. 4 shows relationship between maximum velocity (V_{max}) of individual sliding episode and FC. V_{max} increases with FC at first and then is followed by decrease with further increase of FC after FC is greater than 40%. The results presented in Figs. 3 and 4, and also the landsliding phenomena recorded by cameras show that the landsliding transforms from retrogressive one to fluidized type with the increase of FC, and then transforms to retrogressive sliding with further increase of FC after FC > 40%.

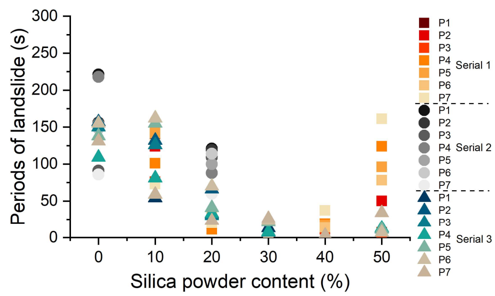

Fig. 3 Relationship between period of individual slide episode and FC

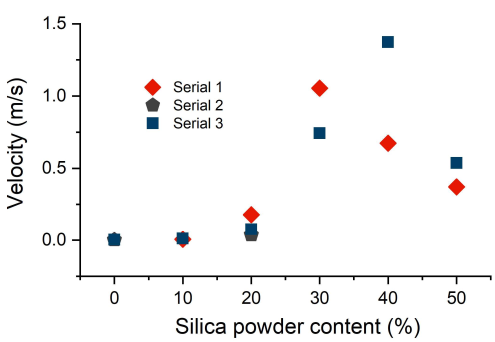

Fig. 4 V_{max} in each individual slide against FC.

Fig. 5 shows various void ratio indexes (including global, equivalent, inter granular, and inter-fine void ratio) against FC. It is seen that the variation of the equivalent intergranular and equivalent inter-fine void ratios with FC show a tendency being consistent with the landsliding durations and V_{max} illustrated in Figs. 3 and 4. Therefore, it is inferred that the equivalent intergranular void ratio could be used to better present the behaviors of mixtures with FC below the FC content of 40%. In the mixtures with FC being less than 40%, the mechanical behavior is dominated by the coarse particles. Once FC becomes greater than 40%, the landsliding behavior will be controlled primarily by fine-grains and therefore the opposite trend was observed.

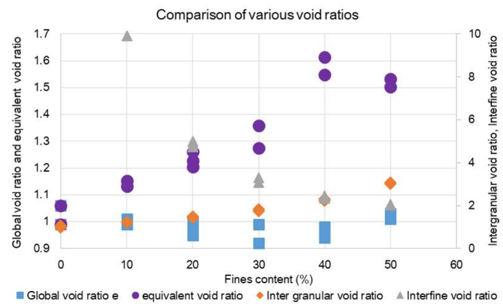

Fig. 5 Various void ratio against FC.

Conclusion

1. The lasting period (Ts) and maximum velocity of individual landsliding revealed that non-plastic fine has a remarkable effect on the initiation and movement of rainfall-induced landslides in flume tests. A threshold for FC was found to be 30-40% in the flume tests. Before this threshold, the Ts becomes smaller and V_{max} greater with increase of FC. However, after this threshold, both of them showed reversed tendency with increase of FC.

2. Equivalent void ratio could be used to better explain the behavior of mixtures with fines. For FC below the threshold, the equivalent intergranular void ratio presents better performance in the interpretation of test results, indicating that the mechanical behavior of the sample is dominated by the coarse particles. However, for FC greater than the threshold, the equivalent inter-fine void ratio showed better performance, suggesting the behavior of mixtures is controlled primarily by fine-grains.