Interactive comment on “Temporary confined water responsible for triggering the landslide of a piedmont gentle slope in Ningzhen Area, China” by Shulan Guo et al.

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In 2010, 7 landslides occurred on the northern and southern sides of Paomashan Mountain. Fig. 3. Near April 7th, the year was very dry, and the accumulated amount of antislip piles and gullies decreased. Fig. 3. In the upper part of the slope, the slope creeps due to creep. But the lower part of the slope was not treated because they believed it is relatively gentle and no subsequent sliding would occur. Using inclinometers to monitor the displacement of the slip body and daily water level gauge to monitor the change of water pressure of the slip body, they set up two monitoring holes in the lower part of the mountain to observe. In June 2016, the lower part of the slip body experienced several times of tension cracks and rainstorms. As shown in Fig. 3, moving the monitoring pile into the upper part of the mountain to experience cracks and causing the end of the slip to move.

According to the field survey, the formation lithology in this slope is roughly divided into three layers, from top to bottom (Fig. 4): silty clay in the surface layer, gravel layer in the middle and bedrock in the bottom. The displacement data of the 12 monitoring holes began to receive on June 24, and the monitoring system began to receive displacement data of the slip body and rainstorms in June 25. However, there was no significant change in the water pressure of the slip body. On July 6, the monitoring system detected a sudden change in water pressure of the slip body. As shown in Fig. 5, the displacement data of the 12 monitoring points were monitored. According to the field survey, the slip body is located in the middle and lower part of the slope. With creep...
The landslide process can be divided into three stages: initial deformation, isokinetic deformation and accelerated deformation.

2.1. Initial deformation

From June 16 to 25, continuous rainfall occurred in Zhenjiang, during which the rainfall reached 45.4 mm. According to the actual monitoring displacement data, the initial deformation of the landslides occurred at 9:00 on the 23rd and was 11 mm, and the initial acceleration was 0.17 mm/s^2.

2.1.2. Isokinetic deformation

Continuous rainfall increased the water content in the slope, and the sliding force gradually increased. On June 26, the slope entered the isokinetic deformation stage, and the deformation gradually increased. The average deformation rate was 1.5 mm/h, and the acceleration range was 8.0-8.6 mm/h. According to the in-situ investigation report, at this time, the number of subsequent deep-seated slides reached its highest level.

2.1.3. Accelerated deformation

From June 28 to July 4, there was continuous heavy rainfall, during which the maximum rainfall reached 19.4 mm/h, and the deformation of the slope increased significantly. At 9:00 on July 1, the slope entered the accelerated deformation stage. In this stage, the deformation rate of the slope accelerated, reaching 1.5 mm/h.

The range of acceleration fluctuated greatly (0.45-0.92 mm/s^2). With the decrease in rainfall, the acceleration gradually decreased, and the landslide structure was the range of isokinetic deformation. However, at this time, the average deformation rate of the landslide was 13.9 mm/h, and the rainfall on the 4th increased to 22.2 mm. The landslide again entered the stage of accelerated deformation. The acceleration increased from 8.0 to 1.1 mm/h, and the deformation rate reached 22.5 mm/h. At this time, the sliding surface was completely connected, and the slope was damaged by sliding.

3. Influence of temporary confined water on landslide

Fig. 4 shows that under continuous heavy rainfall, confined water is formed in the gravel layer in the middle of the slope, with a maximum water head of 1.3 m. Therefore, with the decrease in rainfall and the decrease of water head, the pressure release effect of slope deformation, the water head will gradually decrease, which is called in the "temporary confined water". According to the traditional view, circular sliding generally occurs on the soil slope (Yan et al. 2008; Tang et al. 2014).
The change in the pressure head in the horizontal direction can be roughly divided into unconfined areas and confined areas. In the initial stage of rainfall (0.0 d), the variation in confined water level increases with the increase in unsaturated hydraulic conductivity of the soil. In the middle stage of rainfall (1.0 d), when the rainfall intensity is 150 mm/d and the rainfall duration is 2 days, the confined water level reached a maximum of 13.5 m. In the later stage of rainfall (> 2.0 d), the confined water level reached a maximum of 15 m. Therefore, 150 mm is the optimal rainfall intensity for the formation of confined water.

In addition, rainfall duration also plays a crucial role in the confined water level. Based on the rainfall data in (1995; Jiao et al. 2005; Rosone et al. 2018), it can be seen from Fig. 9 that (1) When the rainfall intensity is 125 mm/d in the early stage of rainfall (< 1.0 d), the water head decreases slightly because it is influenced by the unsaturated water in the unsaturated zone; the supply of the middle and lower parts of the slope is reduced, and the middle stage of the rainfall (1.0 d ~ 2.0 d), the water head increases rapidly because the unsaturated water in the unsaturated zone decreases in the middle and lower parts of the slope in the later stage of rainfall (> 2.0 d), the water head increases rapidly and gradually tends to be stable. (2) When the rainfall intensity is 150 mm/d in the early stage of rainfall (< 1.0 d), the influence of the unsaturated water in the unsaturated zone is smaller. The water head increases rapidly and then confined water is formed in the middle stage of rainfall (1.0 d ~ 2.0 d). In the later stage of the confined water head increasing and the increasing rate of confined water head decreases gradually, in the later stage of rainfall (> 2.0 d), the water head tends to stabilize gradually. When the middle layer is completely filled with rainwater, the groundwater head tends to stabilize gradually. Therefore, when the permeability coefficient of the middle layer is between 0.0001 m/s and 0.0005 m/s, only partially confined water is formed in the upper part of the slope. Therefore, when the permeability coefficient of the middle layer is between 0.0001 m/s and 0.0005 m/s, it is beneficial to form a higher confined water level.

The permeability of the middle layer has a crucial influence on the formation of confined water (Fakley et al. 1995; Jiao et al. 2005; Rosone et al. 2018). Therefore, we studied the confined water level under the condition of different permeability coefficients of the middle layer when the rainfall intensity is 150 mm/d and the rainfall duration is 2 days.

In addition, setting the sliding surface in the interface between the layer of clay and gravel, we use the limit equilibrium theory to analyze the stability of the PS slope, and the results are shown in Fig. 11. The factor of safety at the slope is greater than 1 when there is no moving sand, and the slope is in a relatively stable state, and the factor of safety of the slope is negatively related to the water pressure level in the slope. With the increase in rainfall duration...
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Fig. 8.

C9