The Simulation of Stability of Datangbang Landslide in Wanzhou District of the Three Gorges Reservoir

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Abstract

The landslides along the bank of the Three Gorges Reservoir can cause direct losses nearby the landslide, and threaten coastal people and properties due to potential landslide-triggered waves. Within the impoundment of reservoir water, many landslides reactivated or newly occurred during the rainy season and the annual periodic fluctuation. In this paper, it deals with the characteristics and deformation of Datangbang landslide which is located in the mid part of the reservoir. Based on historical data and field investigation, the deformations occurred mainly during the rainy season and the reservoir water level drawdown. For analyzing the influence of water level fluctuation and rainfall to the landslide stability, the factor of safety (Fs) under different situations is calculated. The key issue is to simulate the variation of groundwater level resulting from the influence of these two factors. The value Fs is calculated under the four summarized stages of reservoir water level combining with the corresponding rainfall or long-term rainfall at each stage. It is concluded that the stability of Datangbang landslide will be mainly affected by the reservoir water fluctuation and rainfall. The results show that the values Fs becomes higher at the rise stage and lower at the drawdown stage of reservoir water level. Moreover, rainfall generally causes the Fs to drop suddenly.

Keywords: The Three Gorges Reservoir, Simulation of stability, Factor of safety, Reservoir water fluctuation, Rainfall

1. INTRODUCTION

According to the thorough investigations since 2000, there are more than two thousands landslides within the area of the Three Gorges Reservoir. With the reservoir impoundment in 2003, many landslides in the Three Gorges Reservoir reactivated or newly occurred which were mainly triggered by the heavy rainfall or the periodical fluctuation of the water level. The reservoir water level fluctuation and heavy rainfall are proved to be the two most important factors to influence the stability of reservoir landslide. In addition, the rainfall caused the landslide stability became worse which related to the rainfall intensity, total rainfall and duration. This paper deals with the stability of Datangbang landslide in Wanzhou district which is located in the mid part of the Three Gorges Reservoir. In order to study the variation of the landslide stability influenced by the reservoir water and rainfall, different scenarios are simulated.

2. GEOLOGICAL BACKGROUD

2.1 Geology

The Datangbang landslide is located on the right bank of the Yangtze River, about 24km upstream from Wanzhou City (Fig. 1). The elevation ranges from 140 to 250m (Fig. 2). The volume is about $3\times10^6 m^3$. Slope angle varies from 10° to 20°. The sliding surface is developed along the interface between Quaternary soil/debris and Jurassic sandstone/claystone. The average dip angle of sliding surface is about 12°. Silty clay and rock debris are mainly consisted of the landslide body in which there are about 35% portion of fragmented rubbles of sandstone. Almost 35% portion of the front landslide is submerged in the highest water level 175m of the reservoir (Fig. 3).

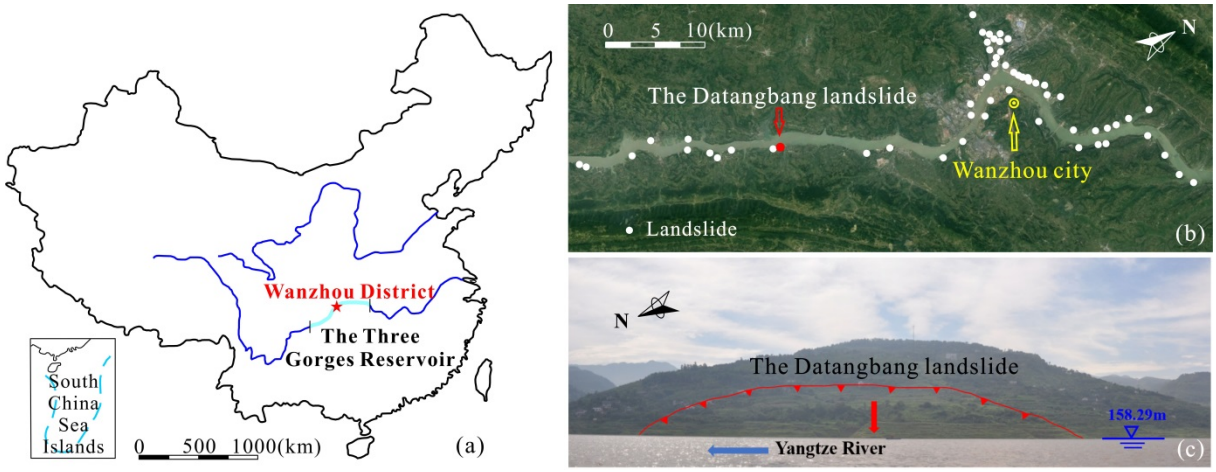


Figure 1. (a) Location of the Wanzhou district, (b) location of the Datangbang landslide, (c) the front view of the Datangbang landslide.

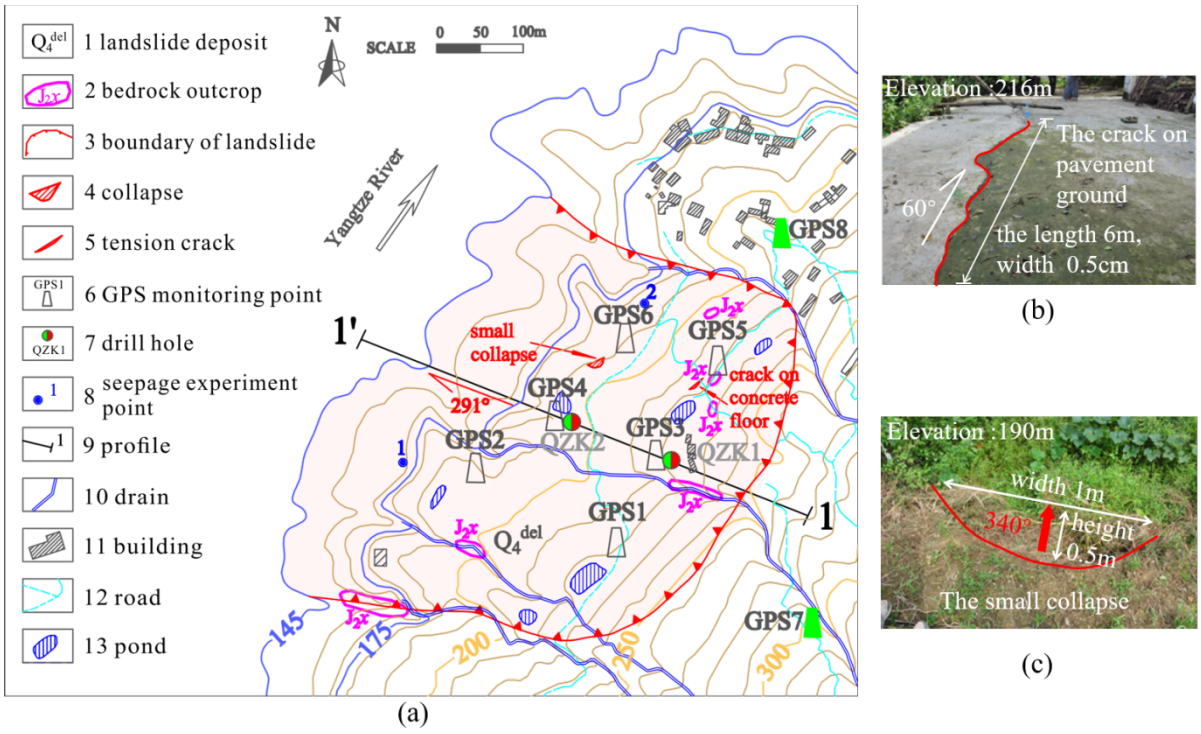


Figure 2. (a) Topographical map of the Datangbang landslide, (b) crack, (c) small collapse.

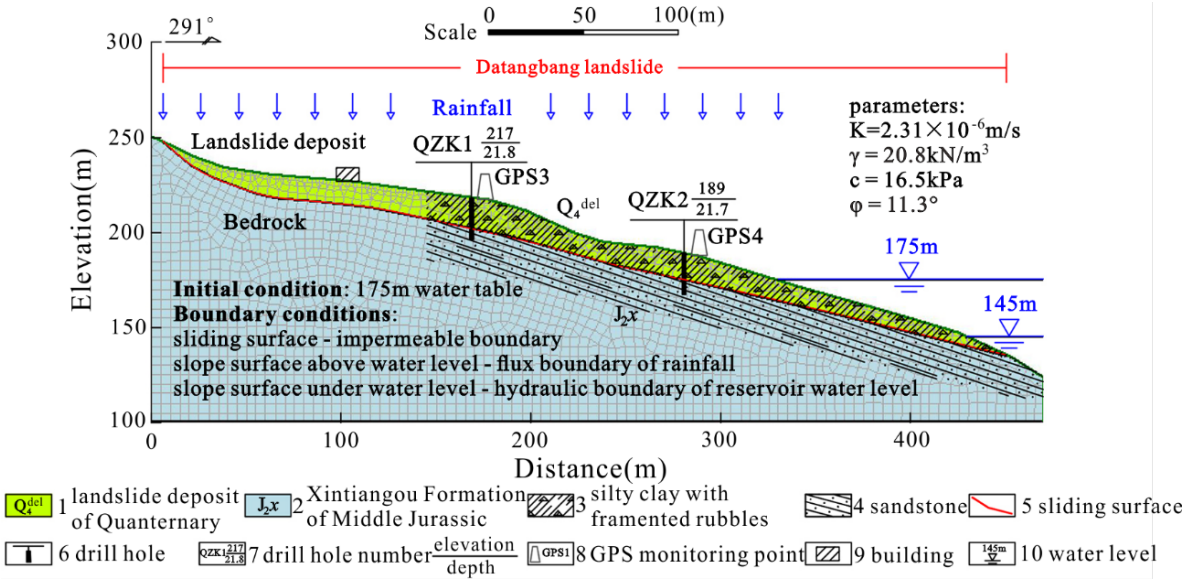


Figure 3. Geological cross-section 1-1'

2.2 Deformation

According to the historical data and field survey, the landslide was initiated during the rainy season in September 1997. The activity of the landslide became significant following the heavy rainfall from 1998 and 2002.

Since the impoundment of TGR in 2003, the tension cracks appeared on the pavement ground as shown in Figure 2. And a small-scale collapse occurred after a rainfall during the field survey in August 2014 (Fig. 2). In addition, the GPS monitoring network was set since 2007 which indicates a movement from point GPS2 (Fig.4).

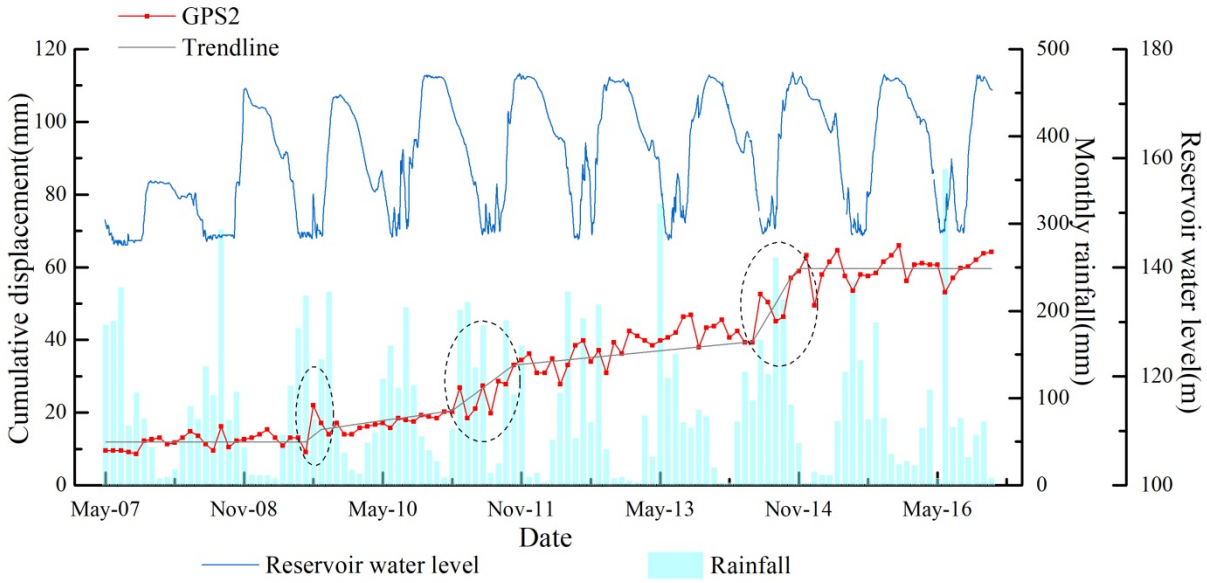


Figure 4. Cumulative displacement of GPS2 between May 2007 and December 2016

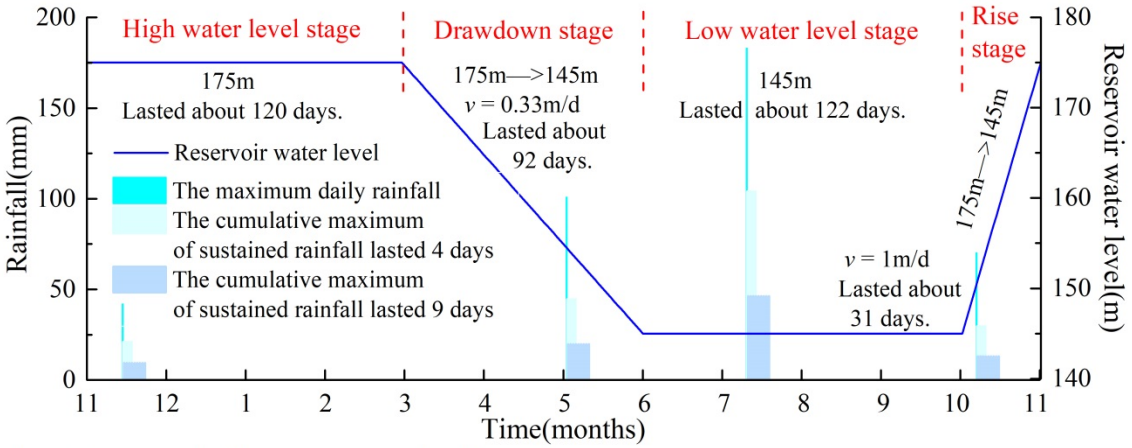
3. SIMULATION OF LANDSLIDE STABILITY

3.1 Method

The GeoStudio software is used to simulate the stability of Datangbang landslide. The 2D finite-element seepage module SEEP/W is adopted to compute the transient seepage and pore water pressure inside the sliding body under different conditions. The result of pore water pressure is sifted to the 2D limit equilibrium SLOPE/W model to calculate the value Fs based on the Janbu's method.

3.2 Summarized simulation conditions

The profile 1-1' is used to establish the calculation model as shown in Figure 3, which is divided into 2300 nodes and 2213 elements. The initial groundwater level is determined through the field investigation and geological exploration. The annual reservoir water fluctuation is summarized as four stages: high water level, drawdown, low water level and rise stage. The corresponding daily precipitation or long-term precipitation in one rainfall process at each stage is considered during the simulation of landslide stability. The P-Ⅲ curve is used to predict the extreme rainfall of 50-year return period based on the statistics of 57-year rainfall records from 1960 to 2016. The simulation conditions are summarized as Figure 5.



Condition 1: one period of the reservoir water level fluctuation
Condition 2: reservoir water fluctuation combined with the single day rainfall (the maximum daily rainfall)
Condition 3: reservoir water fluctuation combined with the long-term rainfall (the cumulative maximum of sustained rainfall) the duration is 4days (3-1) or 9 days (3-2)

Figure 5. The schematic of conditions

3.3 Results

The simulated ground water level in the four stages is summarized in Figure 6, in which the tendency of ground water flow is influenced by the combination of reservoir water level and rainfall. The ground water flow dynamically affects the safety factor of the landslide.

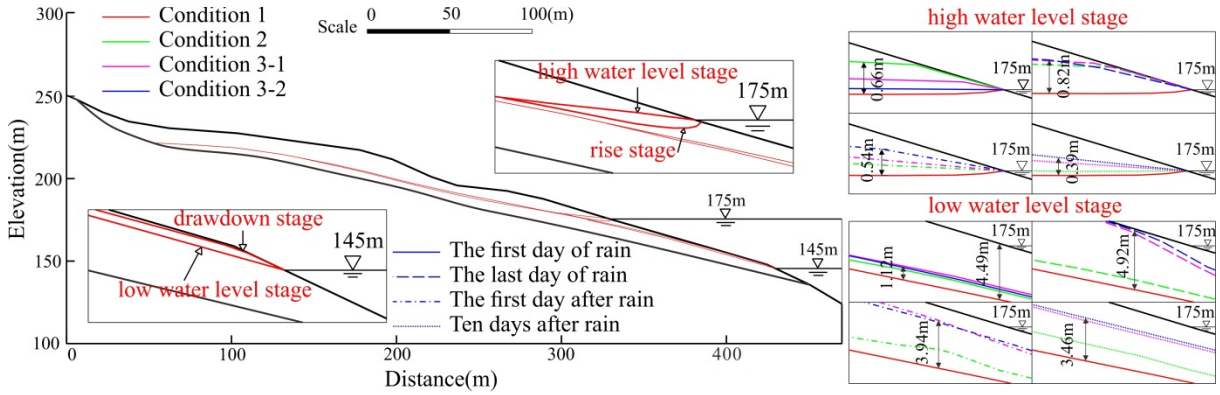


Figure 6. Simulated groundwater level in different conditions

The safety factor of the landslide is computed in Figure 7, which draws the annual variation of Fs values during the whole year. The Fs variation is consistent with the fluctuation of reservoir water level. In the drawdown stage corresponding to dry season, the groundwater level inside the sliding body declines lagging behind the reservoir water level, and the Fs decreases while the rate becomes smaller with time. In the rise stage, the groundwater level rises lagging behind the reservoir water level, and Fs increases while the rate becomes larger with time. The Fs decreases or increases slightly at the high or low water level stage.

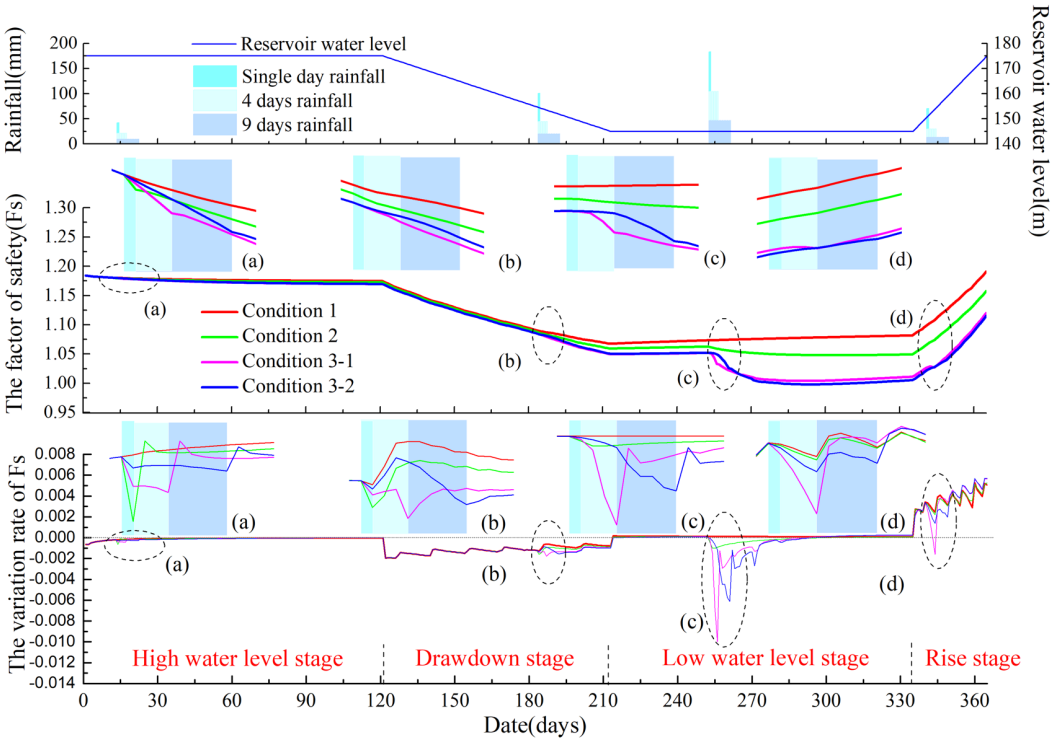


Figure 7. Annual variation of the value Fs of Datangbang landslide

Rainfall can quickly reduce the value of Fs, but it recovers soon. On contrary, reservoir water level affects the value of Fs in a long term tendency. The values Fs of the other conditions are lower than condition 1. Taking the low water level stage as the example as shown in Figure 6 and Figure 7, the groundwater level rises and the Fs decreases while there is rainfall. However, the groundwater level doesn't drop down immediately. The variation rate of Fs becomes smaller. Comparing the condition 2 with condition 3, the former with larger rainfall intensity has the larger decrease rate of Fs at the first day of rain period. For the condition 3-1 with 3-2, the latter has the lower Fs due to longer rainfall duration.

4 CONCLUSION

The stability of the Datangbang landslide is significantly influenced by the reservoir water fluctuation and rainfall. The annual variation of safety factor is related to the fluctuation of reservoir water level during which rainfall causes Fs temporarily variation. The landslide becomes more stable while the reservoir water level rising. On contrary, the stability is getting worse while water level dropping down. During the period of constant water level, the landslide stability changes slightly, but Fs may change quickly due to rainfall and then recover.

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