Response of an old landslide to reservoir filling: A case history

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Abstract Unfavorable hydrodynamic evolution is considered as the major cause leading to reservoir slope instability and is often modeled by numerical method. However, this simulation is seldom checked by systematic field instrumentation. Taking the opportunity of filling the Three Gorges Reservoir, a system was established in Xietan landslide to monitor reservoir water level, subground water level, seepage pressure, rainfall and deformation, etc. The monitored data during reservoir filling shows that: (1) The water level rise in the bank lags behind the reservoir filling and the lag time depends on the bank permeability; (2) rainfall-induced subground water rise and its lag time is closely correlated to hourly rainfall, indicating that it is not feasible or sufficient to use daily rainfall for analysis; (3) the effect of inverse seepage during reservoir filling on stability is ephemeral and reservoir filling is the major cause leading to bank instability.

Keywords: reservoir filling, old landslide, monitoring system, water level, deformation.

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1 Introduction

It is generally believed that reservoir slope instability is mainly caused by unfavorable hydrodynamic evolution in the bank due to reservoir filling and/or operation. Many cases of instability were reported both in China and abroad, causing life fatalities and economic losses, and even leading to project abandonment[1−5]. Riemer[5] reviewed 60 published case histories and indicated that 85% of slide events happened during construction and/or filling period, or within 2 years after completion of the project. ICOLD committee on reservoir slope instability[1] further indicated that 75% of reservoir landslides were the reactivation of old landslides. So it is important to monitor the hydrodynamic evolution and deformation of an old slide during reservoir filling both for the investigation of reactivation mechanism and for hazard control. Taking the opportunity of filling the Three Gorges Reservoir, a system is established to monitor Xietan landslide in Zigui County, Hubei Province, China. This paper introduces the system and its related results.

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2 Xietan landslide and its monitoring system

Xietan landslide is located in Zigui County, Hubei Province, 36 km upstream of the Three Gorges dam. The slide lies on the left bank of the Yangtze River, where local bank is of concave shape and dips to S20°W at an average angle of 22°. The slide is on a reverse slope and confined among a U-shaped hill ridges with a volume of around 6×10^6 m^3. From toe to rear, 4 terraces are developed, i.e. Xintan Town, Middle School, Wangjiawan Village and Pool respectively after their location (Fig. 1).

Geology of the slide is illustrated in Fig. 2. The main body is loosely structured and quite permeable. The slip band is around 2—3 m thick, composed of deep grey or light green soil containing coarse particles of sub-rounded shape. The sliding-disturbed zone lies between the slip band and the bedrock and is composed of firm soil mixed with coarse particles and located mainly at the toe. The permeability of both the slip band and

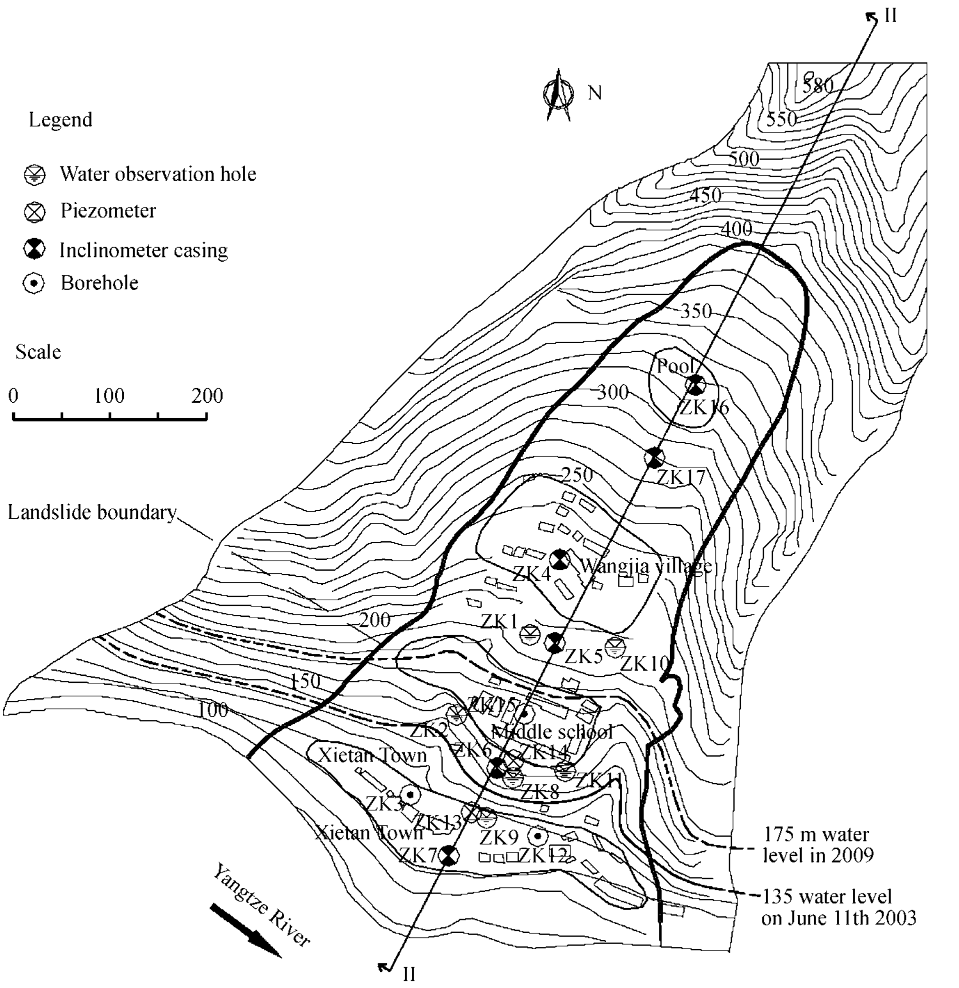

Fig. 1. Plan view of Xietan landslide.

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the sliding-disturbed zone is lower. Bedrocks are clastic rocks from mid Jurassic period to mid Triassic period.

During the 2nd stage of filling, the reservoir water level would reach from around 80 to 135 m, submerging the toe of the slide. So the monitoring system is mainly established in the front part, as shown in Table 1, Figs. 1 and 2.

Table 1 Instruments for monitoring Xietan landslide

SN	Monitoring item	Instrument	Amount	Installing place
1	Rainfall	RG2-M rain gauge	1	top of school building
2	Subground water level	Geoken4500s piezometer	5	ZK1, ZK8－ZK10
		SWJ-90 flat tape water level meter	1	ZK2
3	Seepage pressure	GEOKON4500s piezometer	5	ZK13－ZK15
4	Reservoir water level	water gauge	73 m	upstream of landslide
5	Deformation	SINCO inclinometer	1 set	ZK4－ZK7, ZK16, ZK17
6	Data acquisition system	VW-403 datalogger	1	indoor
		DGK196 multiplexer	1	
		notebook computer	1	

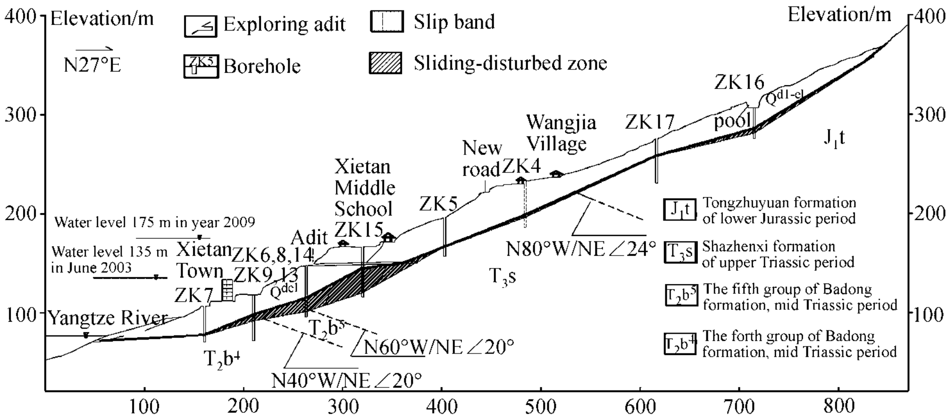

Fig. 2. Longitudinal cross section II-II.

3 Hydrodynamic response

Both ZK9 and ZK10 are observation wells of subground water and are used to analyze the hydrodynamic response of the landslide.

The water level in ZK9 is affected by reservoir filling. In general its water level rise lags behind the reservoir filling (Fig. 3). However, once the reservoir level reaches the top surface of local slip band, its water level soon becomes consistent with the reservoir level, indicating that the main body is more permeable than its underlying slip band, sliding-disturbed zone and bedrock.

The water level in ZK10 is not affected by reservoir filling, but by rainfall infiltration.

Rainfall infiltration takes time, which depends on the rainfall intensity. For ZK10, its water level fluctuates around the local slip band and will rise after rainfall (Fig. 4). Though daily rainfall is widely used in engineering, the water level rise is more closely related to hourly rainfall, as shown by the rainfall events on July the 4th and 17th (Table 2).

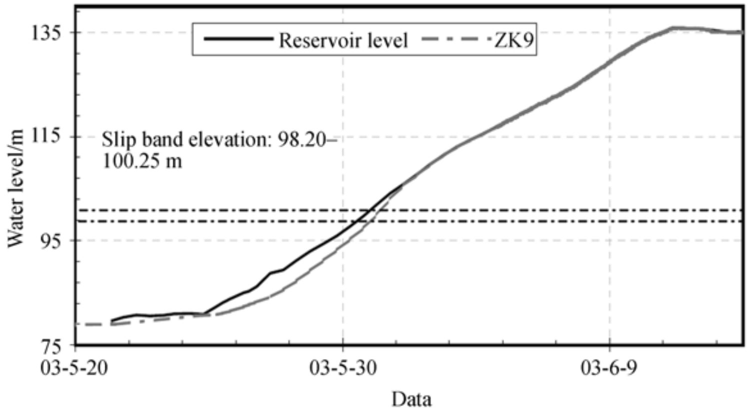

Fig. 3. Water level in ZK9 vs. time.

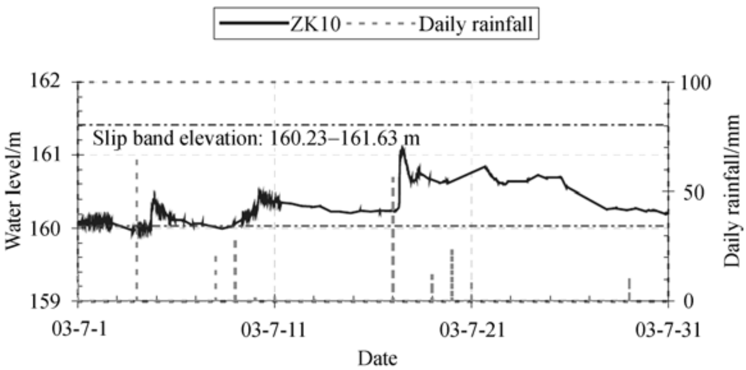

Fig. 4. Water level in ZK10 vs. time.

Table 2 Effects of rainfall on subground water level

Date	Daily rainfall /mm	Hourly rainfall/mm	Water level rise/m	Rise rate/mm·h^{-1}	Lag time/h
2003-7-4	64	10.7	0.426	0.133	9.96
2003-7-17	50.2	27.1	0.768	0.364	4.58

4 Deformation response

Monitored deformation shows that: (1) the deformation is caused by reservoir filling and the deforming zone (ZK5, ZK6, ZK7) lies in the front part of the slide. Rainfall infiltration has little effect; (2) the deformation is mainly the shear deformation along the slip band (Fig. 5); (3) the effect of inverse seepage to slide stability during reservoir fill-

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ing is ephemeral. During early stage or when reservoir water level exceeds local slip band, the slide deforms toward the bank (Fig. 6), being ephemerally favorable for the slide stability, but the general trend is toward the reservoir. This may explain why so many reservoir slides are reactivated during filling.

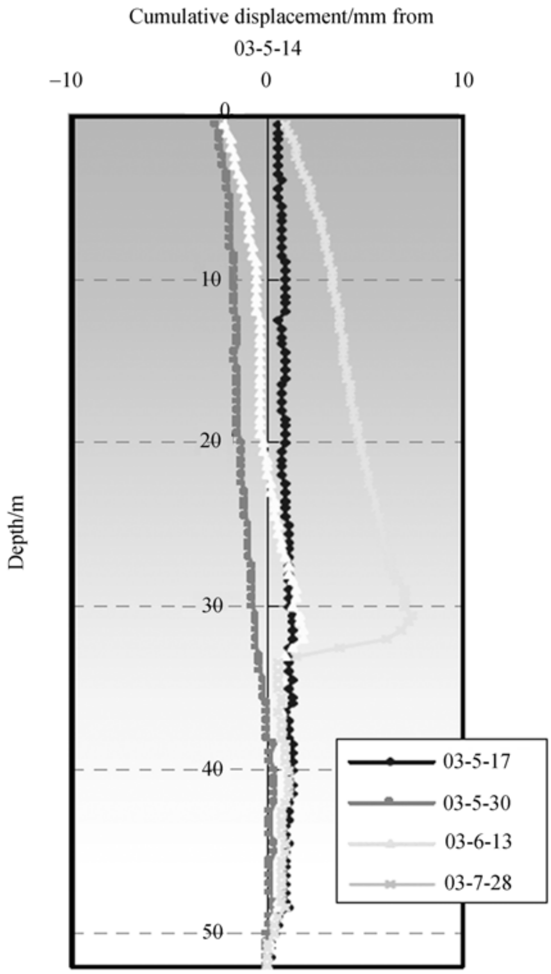

Fig. 5. Cumulative displacement of casing ZK6.

5 Conclusions

A monitoring system is implemented in Xietan landslide, the Three Gorges Reservoir area with data up to now obtained. The monitored data during reservoir filling indicate that:

(1) The water level rise in the bank lags behind the reservoir filling and the lag time depends on the bank permeability.

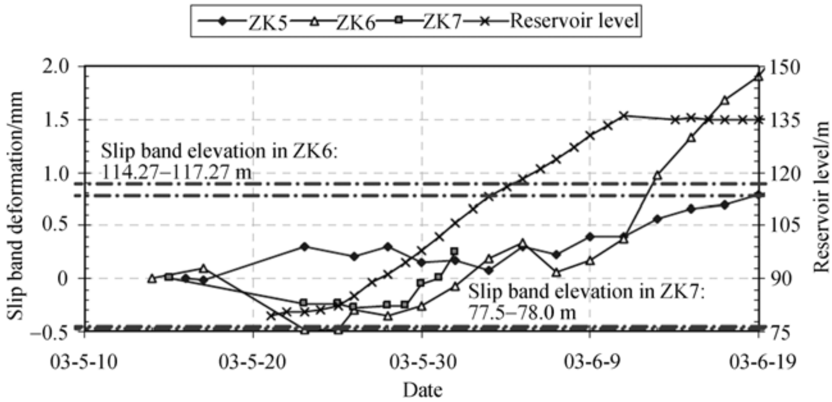

Fig. 6. Deformation response during reservoir filling.

(2) Rainfall-induced subground water rise and its lag time are closely related to hourly rainfall, indicating that it is not feasible or sufficient to use daily rainfall for analysis.

(3) The effect of inverse seepage during reservoir filling to stability is ephemeral. Reservoir filling is the major cause leading to bank instability.

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