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Stability assessment of an ancient landslide crossed by two coal mine tunnels

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ABSTRACT

In 2005, when two main tunnels were excavated in Faer Coal Mine, Guizhou Province, China, an unknown ancient landslide, subsequently named Dazhai landslide, was encountered. Roof caving, large convergence and severe support damage in the tunnels, as well as several ground subsidence occurred. The two tunnels have been kept stable after an inner supporting treatment in 2008. However, since a heavy rainfall in July 2010, some transverse cracks were observed at the landslide toe, determining significant additional costs over the normal administration of the mine. Invited by the owner, we performed a comprehensive investigation to evaluate the stability of Dazhai landslide crossed by two main tunnels. Firstly, field surveys and mappings were completed to obtain a preliminary delineation of the landslide surface, and a geological drilling along the central landslide axis was accomplished to depict the sliding surface. After that, a monitoring system containing a GPS–RTK network and six observation sections in one tunnel were established and a 12-month monitoring was conducted. Moreover, to obtain an overall comprehension, numerical simulations were carried out by using GeoStudio and FLAC^{3D} software. The results from site drilling, monitoring and simulations indicate that the Dazhai landslide is stable as a whole, and only local shallow landslides might occur. The local instability of Dazhai landslide has limited impact on the safety of the two main tunnels. This conclusion has led to a budget savings of over RMB 40 million.

1. Introduction

Triggered by natural phenomena or human actions, landslides are referred to as geological events which involve down-slope transport of soil and rock materials such as rockfalls, deep failure of slopes and shallow debris flows, etc. Because these natural hazards can cause considerable damage and loss of lives and properties, they have been intensively investigated by many researchers over the past years (Wei et al., 2006; Bednarik et al., 2010; Alejano et al., 2011). So far, in order to better investigate, predict landslide stability and mitigate the effect of the hazard, a variety of approaches both qualitative and quantitative, including monitoring, measuring, model test, and numerical simulation, have been implemented (Korup, 2005; Kaynia et al., 2008; Song et al., 2009; Jia et al., 2012; Jiao et al., 2012; Marcato et al., 2012).

Many kinds of uncertainties are often associated to the triggering and propagation of landslides. Some of these natural hazards can lead to severe threat to the excavation of underground opening such as mining tunnels as the gateways or accesses to mine area (Torano et al., 2002; Fujii et al., 2011; He, 2011; Coggan et al., 2012; Wang et al., 2012). In particular, when dealing with ancient landslides crossed by mine tunnels, challenges are considerable. As a general rule in underground engineering, when hazardous zones like landslides or large faults are found, they are avoided by modifying the tunnel axis position. Nonetheless, in some cases, it's inevitable to intersect an unexpected ancient landslide which has not been previously considered due to poor and inadequate geological exploration. The Dazhai landslide lies in such a context since it was recognized only during drillings of the mine tunnels (Figure 1).

The study area is located in the mine field of Faer Coal Company, Guizhou Province, China. In 2005, after the inclined parts of the tunnels were completed, the landslide was found without prior notice; later in 2006, a targeted exploration allowed to further identify the landslide as an ancient one (Figure 1). During excavation, the surrounding rocks of two tunnels presented large deformations with severe top falling and rib spalling, and then directly transmitted to the surface resulting into a series of subsidence features. These deformations were partially contained after that supporting systems (steel arch and shotcrete-bolt) were installed. Nonetheless, this landslide was still presenting severe threat to the stability of the tunnels, the entire mine safety and production. On one hand, a huge investment on the tunnel serviceability had been already made; these tunnels had been designed to contribute to the mine production for over 100 years and can stand extreme conditions of earthquake and downpour; in 2009 belt conveyors had been installed in the tunnels as well. On the other hand, it would be very difficult and thus expensive to systematically implement a thorough rock reinforcement plan of the most sensitive part of the landslide volume which had been estimated at 24 million m^3 roughly costing about RMB 40 million. Moreover, after a heavy rain in July 2010, some transverse cracks

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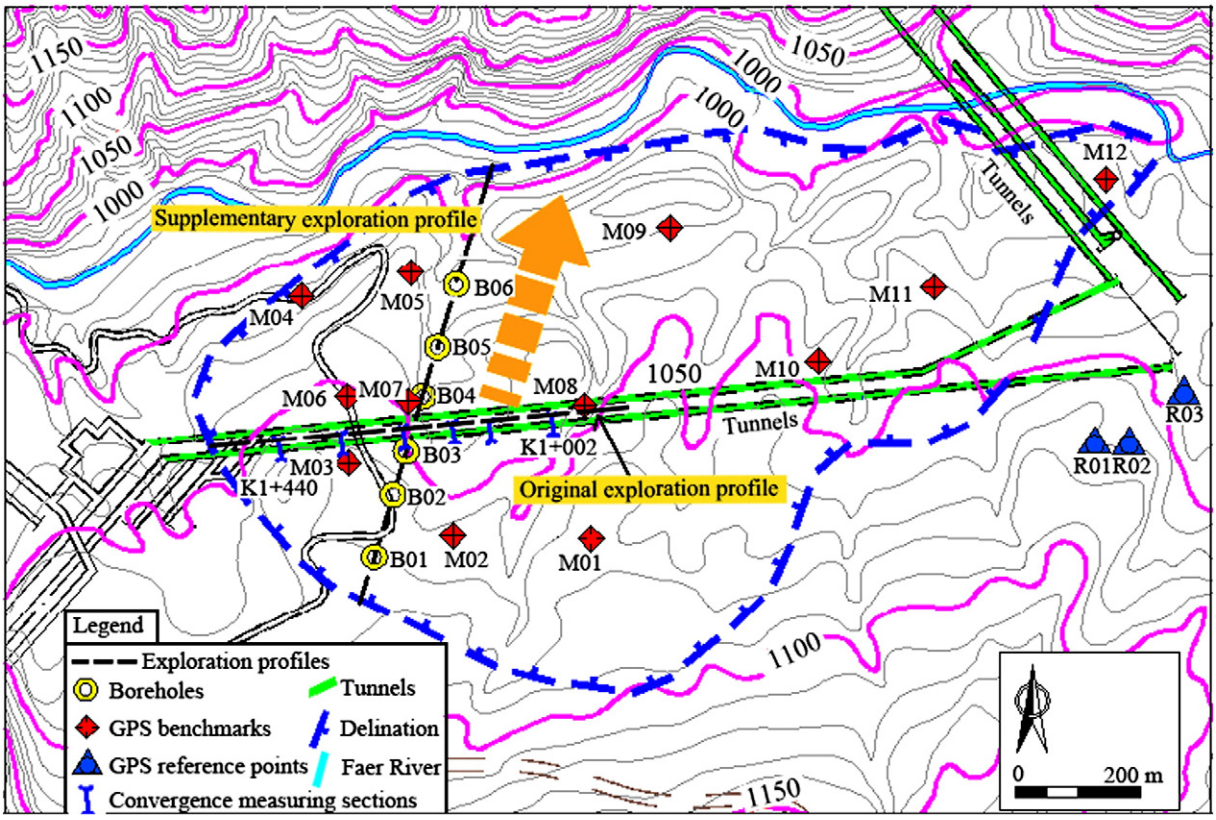

Fig. 1. Topographic map of Dazhai landslide with schematic locations of the tunnels and measurement sections.

have been observed at the landslide toe (Figure 2), determining significant additional costs over the normal administration of the mine.

In this context, a risk assessment of the Dazhai landslide was commissioned with the purpose of determining an optimum management of the mine tunnels from a geotechnical viewpoint. For this objective, field surveys, drillings and 12-month GPS–RTK monitoring were conducted, and then the numerical simulations by means of GeoStudio (GEO-SLOPE International Ltd., 2007) and FLAC^{3D} (ITASCA Consulting Group, Inc., 2002) software were performed for further verification.

2. The study site

The landslide area is characterized by a hilly landscape with a relative relief of about 70 m and covers an area of 0.86 km^2. The northern

Fig. 2. Transverse cracks at the toe of Dazhai landslide.