Potential Slope-Failure Hazards of the Batongguan Historical Trail in the Yushan National Park, Taiwan

Keng-Hao Kang [(1*)], Ming-Wan Huang [(2)], Chu-Chun Lo [(2)], Shun-Hsing Yang[(3)], Yii-Wen Pan [(1)] and Jyh-Jong Liao [(1)]

(1) Department of Civil Engineering, National Chiao Tung University, Taiwan
(2) Disaster Prevention & Water Environment Research Center, Taiwan, National Chiao Tung University, Taiwan
(3) Yushan National Park Headquarters, Taiwan
(*)E-mail: kangkanghk@gmail.com

Abstract

The Batongguan Historical Trail is an east-west traversing trail in the Yushan National Park built in 1921. This trail, with a gentle slope, was built to transport heavy military supplies in the Japanese Colonial Era. Since 60's, it has become a popular mountain hiking trail. After the 1999 Chi-Chi earthquake and several typhoons with heavy rainfall, a couple of sections within the trail were detoured to steep by-pass routes due to slope failures. The worst section is the one connecting Guangao and Batongguan, where was severely damaged by the typhoon Morakot in 2009. Multi-staged stereoscopic pairs of aerial photographs from 1980 to 2010 were used to identify the potential hazards caused by the slope failures. Afterwards, field investigation was conducted to investigate the slope failure features along the section connecting Guangao and Batongguan of the Batongguan Historical Trail. The results show that most the slope failures in the detoured trail between Guangao and Batongguan were caused by headwater erosion.

Keywords: Yushan National Park, Historical Trail, Potential hazards, Slope failure

1. Introduction

The Batongguan Historical Trail begins Dongpu, Nantou in the west, ending at Yuli, Hualien in the east with a total distance of about 116km. This pathway has a width within 1.2 and 1.8 meters and an altitude from 140 to 3280 meters. It was opened in January, 1921. This trail was regarded as an East-West traffic renovation by the Office of the Governor – the general during the Japanese Colonial Period.

Since 60's, the Batongguan Historical Trail has become a popular mountain hiking trail. The 1999 Chi-Chi earthquake hit central Taiwan with its epicenter in Chi-Chi, Nantou. The earthquake triggered lots of landslides (Liao, 2000). As a result, the Batongguan trail was closed because of safety reason for two years. In 2009, the typhoon Morakot brought 1623mm of rainfall within 24 hours in the area (Jou et al., 2010). This event resulted in many slope failures along the Batongguan Historical Trail; the trail had to detour in many places, especially from Guanggao to Batongguan. The detour path has to hike 300 meters of elevation, 1 more kilometer of distance, and takes threefold time to pass this detour area (Fig.1, Fig.2). In this work, we used multi-staged stereoscopic pairs of aerial photographs from 1980 to 2010 to identify the potential hazards caused by the slope failures, and field investigation to explore the slope failure features in the section between Guangao and Batongguan of the historic trail.

2. Site backgrounds

2.1 Topography

The Batongguan Historical Trail in Nantou was built along the right bank of the Chenyoulan River, along north-west direction (Fig.1). From Dongpu to Batongguan, the altitude rises from 1156 to 2824 meters. Except the detour section, the trail was in general built along the mountainside. In the detour section, the trail reaches the ridgeline 600 meters away from the north of Guangao. After passing the detour section, the trail returns to the mountainside leading to Batongguan.

Most part of the trail is parallel to the Chenyoulan River; the trail turns to the North-East direction when it reaches the head of the Chenyoulan River where

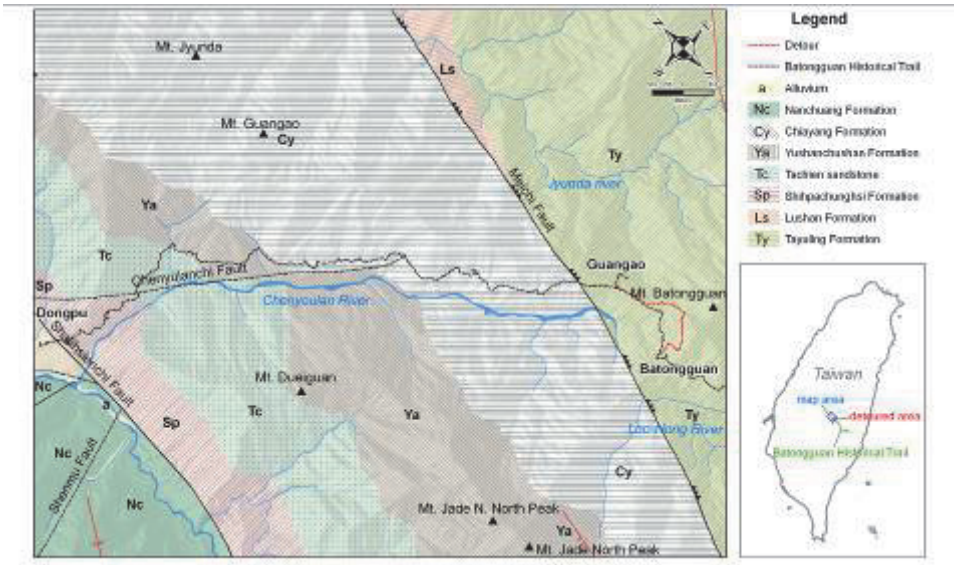

Fig. 1 The geological map of the Batongguan Historical Trail western section.

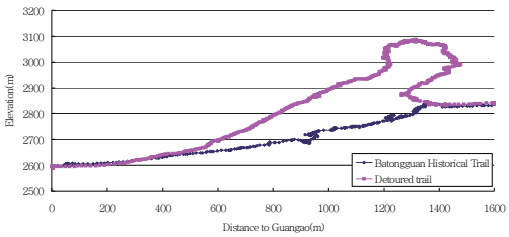

Fig. 2 Elevation difference between the old trail and the detoured trail.

the detoured section of the trail is located.

2.2 Stratigraphy

According to the report of Taiwan Central Geological Survey (Central Geological Survey, 2008), the strata in the region covering the trail can be divided into five formations based on rock type classification (Fig.1).

(1) The Tayuling Formation (Ty) is mainly composed of slate with occasional thin layers of meta-sandstone.

(2) The Chiayang Formation (Cy) is mainly composed of slate with occasional thin layers of meta-sandstone.

(3) The Yushanchushan Formation (Ya) is mainly composed of interlayers of meta-sandstone and slate, slate with thin-bedded sandstone, and some thick layers of meta-sandstone.

(4) The Tachien sandstone (Tc) is mainly composed of meta-sandstone with thin layers of slate occasionally. The mineral grain size of the meta-sandstone is medium to coarse.

(5) The Shihpachunghsi Formation (Sp) is composed of slate with thin layers (a few centimeters to tens of centimeters) of gray meta-sandstone, interbedded slate and meta-sandstone.

The strata between Guangao and Batongguan belong to the the Tayuling Formation.

3. Interpretation of aerial photographs

To understand how serious the Batongguan Historical Trail was damaged, we used multi-staged stereoscopic pairs of aerial photographs to identify the potential slope failure area, the aerial photographs were taken in year 1980, 1988, 1996, 2000, 2007, and 2010. We compared and interpret the aerial photographs taken in different years; the attempt was to identify the failure mechanism in the detoured trail area.

At the detoured area, the trail and the topography in the aerial photographs are very similar up to 2000, which was one year after the Chi-Chi earthquake. Since 2000, the headwater erosion of an unnamed stream in the detoured trail area became more and more serious (Fig. 3). Before 2000, the unnamed stream was joined by 3 tributaries. Most of the landslides distributed in tributary II, rest of the landslide distributed in the left bank of tributary I. The Batongguan Historical Trail was then covered by plants, hard to be identified from the aerial photographs.

In 2007, the headwater erosion developed further, especially along tributaries I and III. More landslides took place, especially the landslides distributed along tributary I. The landslide D expanded because two landslides had joined together. The landslide E was also formed, the ridgeline was toward south. There were also landslide F and G formed along the tributary II and the unnamed stream. The pre-exist landslides along the tributary II, the landslide B were expanded, but landslide A and C were not.

In 2010 (one year after typhoon Morakot), a new

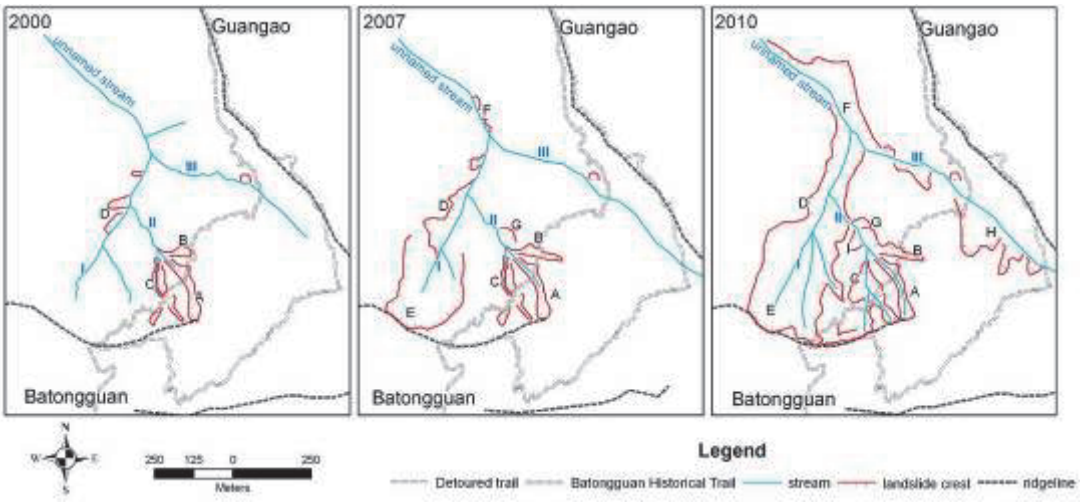

Fig. 3 Identify result of stereoscopic pairs of aerial photographs between year 2000 to 2010, it shows the tributaries start to show up and the landslide area are getting bigger.

tributary was formed and almost all the landslides distributed along tributary I had joined together. Because of the headwater erosion, the ridgeline moved further south. The landslides along tributary II, landslide A, B, C expanded; a new landslide I was formed. On tributary III, there were at least three landslides formed after typhoon Morakot. The landslide F distributing along the right bank of the unnamed stream also expanded into a large landslide.

Based on the identified results of stereoscopic pairs of aerial photographs from 2000 to 2010, it appears the tributaries started to show up and the landslide area expanded. The ridgeline in the north of Batongguan moved further south. It appears the major cause for the development of the slope failures should be attributed to headwater erosion.

4. Results of field investigation

To examine the slope failure modes of the detoured area, we conducted field investigation along the Batongguan Historical trail in April, 2015. The slope along the Batongguan Historical Trail is still unstable. Debris from upper slope covers half of the trail, the thickness of debris is about 10 to 30 centimeters. The detoured trail between Guangao and Batongguan, is very seriously damaged.

In the landslide H influenced by the major headwater erosion, the colluvial deposit in the tributary III has almost been washed out by runoff. The trail has disappeared; passing the area became very difficult and dangerous (Fig. 4).

The landslide A is similar to the landslide H. The situation in landslide A is the worst part of this trail. The whole trail has disappeared. With barely spot to step on, there was no time and no room for measuring joints over there (Fig. 5). Most of the soil and weathered bedrock do not exist in the gullies; they were all scoured by runoff. The rock outcrop over there is lightly weathered slate, with high angle cleavage and at least two sets of joint in oblique angles that cause rock block failure.

The trail slight cut through landslide C, which expand very fast since year 2000.

Fig. 4 Picture of the destroyed trail caused by the landslide H.

Fig. 5 Picture of the destroyed trail caused by the landslide A.

5. Results of topographical analysis

We used the Digital Surface Model (DSM) produced from stereoscopic pairs of aerial

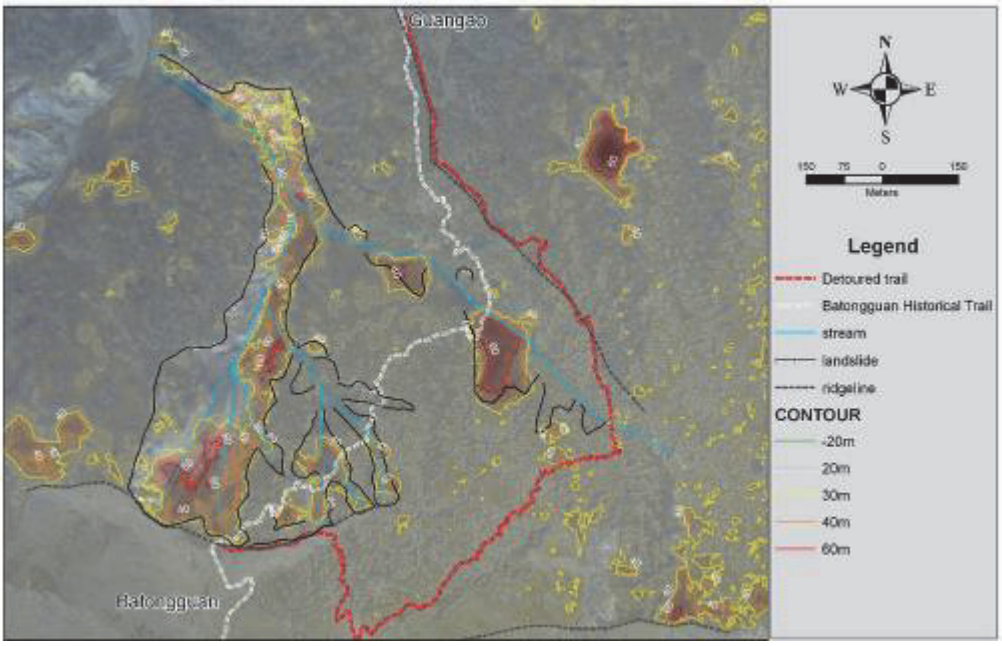

Fig. 6 Elevation difference between year 2007 and 2010 compare with identify result of stereoscopic pairs of aerial photographs.

photographs to calculate and compare the elevation between 2007 and 2010 (Fig. 6). Comparing the surface elevations in 2010 and 2007, it was found the surface elevation in the tributaries significantly decreased. It implies the right bank of tributary I was subjected to severe erosion. As a result, more landslides occurred from 2007 to 2010. The upper stream side of the trail passes through tributary III; the landslide H was formed over there, and the surface elevations decreased a lot. The area is where the original trail disappears.

6. Conclusions

The Batongguan Historical Trail in the Yushan National Park was serious damaged by large-scale landslides after the 1999 Chi-Chi earthquake and the 2009 typhoon Morakot in 2009. The trail has to detour in several sections seriously damaged by large-scale landslides. In this work, site investigation for the large-scale landslides along the Batongguan Historical Trail was conducted. The site investigation made use of stereoscopic pairs of aerial photographs to interpret the distribution and the cause of the landslides. Field investigation was followed to confirm the interpretation by remote sensing. Most the slope failures in the detoured trail area in the western section of Batongguan Historical Trail were caused by headwater erosion. The damage of trail was especially serious when the trail went across a stream. Once the debris or deposit materials were washed away by runoff during a heavy rainfall, the trail would be destroyed. In some cases, the trail may be covered by large amount of debris so that block the trail as well.

The tributaries between Guangao and Batongguan area expanded quickly in width and slope angle and so that the upper slopes were difficult to maintain stability. Many parts of Batongguan Historical Trail from Guangao to Batongguan are no longer existing; thus, it is extremely dangerous for hikers to pass through. The landslide area is still expanding so far. For safety concerns, steep by-pass routes passing near the ridgeline are recommended at present.

Acknowledgements

This research was supported by the Yushan National Park Headquarters, Taiwan.

References

Central Geological Survey (2008) Geological Investigation and Database Construction for The Upstream Watershed of Flood-Prone Area. (First phase)- Geological Investigation, Landslide-Debris Flow Investigation and Their Susceptibility Evaluation in the Watershed Area (1/3).

Ben Jong-Dao Jou, Yi-Chiang Yu, Feng Lei, Yung-Ming Chen, Cheng-Sheng Lee, Ming-Dean Cheng (2010) Synoptic Environment and Rainfall Characteristics of Typhoon Morakot (0908), Atmospheric Sciences , Vol. 38, No. 1, pp. 21-38.

Hsuan Wu Liao (2000) Landslides Triggered by Chi-Chi Earthquake. Institute of Geophysics, National Central University, Taiwan.