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Critical Rainfall and Slope Hazards in Central Taiwan Mountain

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Abstract - Monsoon season and typhoons often entrain large amounts of water vapour to cause concentrated rainfall in the Taiwan mountains. Flood disasters and debris flow often occur because of heavy rainfall. The invasion of earthquakes and heavy rain and the extensive development of various hillsides often increased the probability of slope damage. The rainfall was considered as the main factor of slope failures. The historical rainfall data of slope failure at Nantou 89th County Road caused by rainfall was compiled, and the slope failure management based on the rainfall was set. In this study, the radar echo data was used to obtain the rainfall data (R). The radar echo data were provided by the Central Meteorological Administration. The radar echo value (DBZ) of the Nantou 89th County Road showed a good relationship between the cumulative DBZ and R. This study collected rainfall and slope failure events at 49K in Nantou 89th County Road. The cumulative rainfall R, rainfall duration T, rainfall intensity I, IT-type alert mode were compared to obtain the critical rainfall. The critical rainfall range of the slope failures develop at 49K is about 270mm. If the average rainfall (I) exceeds 7.5mm and rainfall duration (T) above 40 hours, slope hazards may also happen.

***Keywords*:** Failure Processes, Slope, Landslide, Hazards, Critical rainfall.

1. Introduction

Rainfall in Taiwan is usually concentrated in the rainy season from May to October every year. Typhoons also occur very often during this period and cause concentrated rainfall in mountainous areas. Severe floods and erosion usually take place due to heavy rainfall. Thus, the accumulated rainfall may cause disasters such as debris flow, slope collapse and landslides. The research area of this paper mainly aims at No. 89 Road, Renai Township, Nantou County in central Taiwan mountain areas. In 2004 and 2006, Typhoon Mindulle 0609 flood had brought the cumulative rainfalls up to 1,215 mm and 1,810 mm, respectively, resulting in severe road hazards. Therefore, this research will focus on the critical rainfall that caused the slope damage and the range of the slope hazards.

2. Study Area and Geology

Nantou 89th County Road is located in Renai Township, between the Lishan and Wushe, as shown in Fig. 1 [1,2]. The total length of the road is about 53.23 km, and its direction is from northeast to southwest. The ends of the northern and southern roads are connected to Taiwan Highway Number 8 and14-A, respectively, and the road width is about 3 to 6m. The type of road belongs to the local industrial road, and some sections of the slope along the route are quite steep. The geological condition within this region is very broken and fragile, and the mountain slopes along the road are in serious condition. 89th County Road had been struck by an earthquake, typhoons, and flood disaster in recent years. The traffic will be disrupted almost whenever it encounters heavy rain because of the disasters. The serious disaster mainly occurs after continuous rain or heavy rain. The study mainly discusses the 49K collapse case on No. 89 Road [1]. The rock layer of the central ridge mountain range is strongly compressed, resulting in a large-scale complex syncline, and the syncline axis is inclined to the south [3]. The Meixi fault is located on the northwest side of the No. 89 Road in the northeast to southwest direction. The geological strata in the adjacent area are the Lushan formation (Ls) and the Meixi sandstone (Ms). This study area belongs to the Wuxi River Basin, which has two water systems, the Beigang River and the Meixi River. The study area is dominated by the Beigang River, which originates from the western slope of Hehuan Mountain, Renai Township.

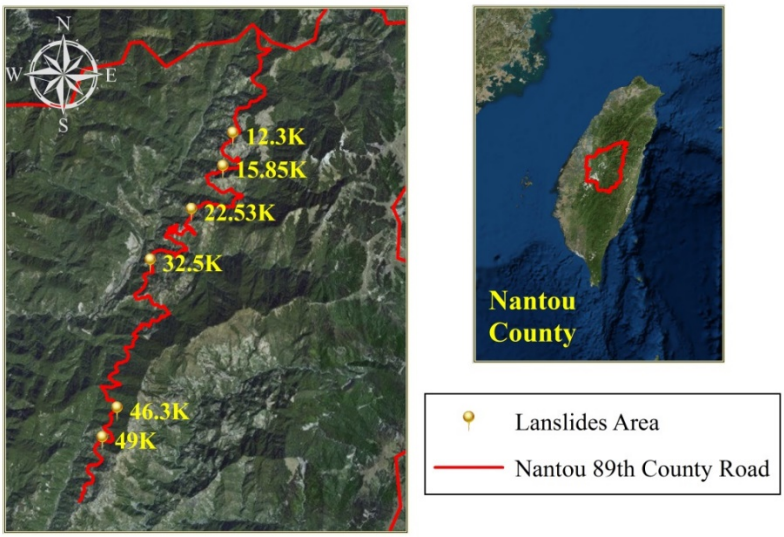

Figure 1 Location map of the study area. (Xie Sheng Ltd., 2016)

3. History of Road Hazards

The collapsed areas and road locations were found based on the orthophotos. The collapsed areas and road locations were drawn after overlapping the aerial photographs of the past years. However, the orthophoto images can tell the condition of the bare zone in the year. Still, it is hard to accurately determine which typhoon or torrential rain event caused the landslide. Figure 2 is an orthophoto of 49K taken in 1980 [4]. The red line is the road now, the blue dotted line is the valley on the downhill, the east (to the right) is the direction to Lishan, and the west is the direction to Wushe. The yellow dotted area is the damaged area. According to the aerial photos, areas a and b are likely to be farming phenomena, and there are also roads in and out of farming. From the aerial photo of Figure 3 on September 6, 2009 [2], the place has experienced several Typhones, such as Taozhi, Minduli, Begonia, and Masha, and heavy rainfalls. The original damaged area of C1, shown in Figures 2 and 3, has expanded the collapsed scope of the upper and lower slope due to the above events. The newly collapsed area C2 could be caused by the erosion of the valley creek (the blue dotted line in Figure 2).

4. Rainfall Estimation and Critical Rainfall

The radar echo method is used to estimate the rainfall of each rainfall event. The real-time radar echo data are obtained from the Central Meteorological Administration [5]. The measurement unit used for radar echo is DBZ, and the hourly DBZ value of the rainfall station can be obtained. The relationship between the cumulative rainfall and the cumulative DBZ of each rainfall station was obtained by linear regression. The acquired correlation is used to estimate the rainfall for all the rainfall events. Since there are no rainfall stations in this study area, the data of nearby rainfall stations provided by the Atmospheric Hydrology Research Database [6] are used to perform simple interpolation to estimate the rainfall at the desired location. There are three nearby rainfall stations: Cuifeng rainfall station, Ruiyan rainfall station, and Renai rainfall station. The radar echo data provided by the Central Meteorological Bureau are also used to estimate the rainfall.

The assessment of the critical rainfall is found based on the previous information of slope hazards. The accumulated rainfall from 1996 to 2013 are collected, synthesized and analyzed. The judgement of failure or no failure development of each rainfall incident is based on the government or consulting companies' aerial photos and related reports. The average hourly rainfall (I) and rainfall duration (T) for each rainfall event is estimated. Many people used the rainfall driving indicator (RTI) to identify the critical rainfall boundary. The R is the accumulated rainfall and is calculated as T times I, i.e., R=TI. The crucial boundary for the debris flow occurrence is R equals 250 mm in Taiwan. Therefore, the T is plotted against I with R=270 and 350 mm boundary lines shown in Figure 4. As shown in Figure 4, the R for all the failed events is greater than

270 mm. About 80% of the failed cases have R greater than 350 mm. Thus, the critical rainfall boundary for the road at 49K is suggested as R=270 mm. When the accumulated rainfall, R, exceeds 270mm, the slope in 49K may experience slope hazard. If the average rainfall (I) exceeds 7.5mm and rainfall duration (T) above 40 hours, slope hazards may also happen.

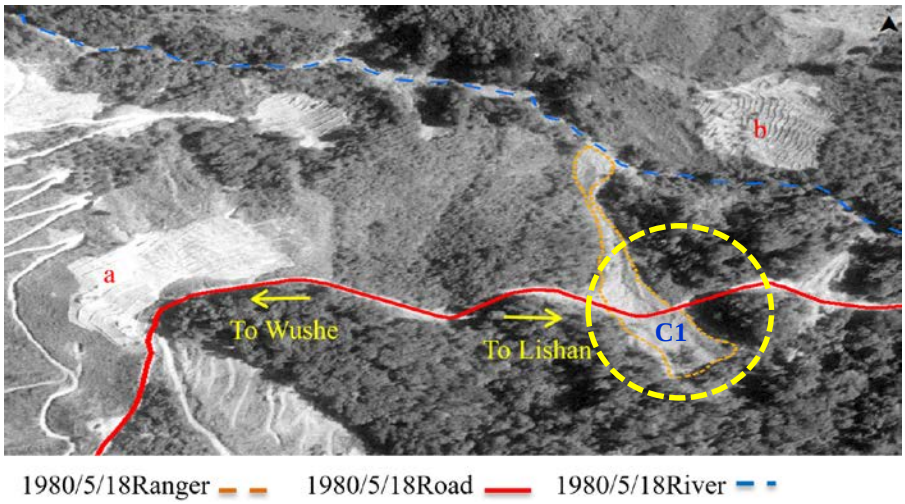

Figure 2 The road and bare area caused by slide from the Aerial photo taken on May 18, 1980 [4]

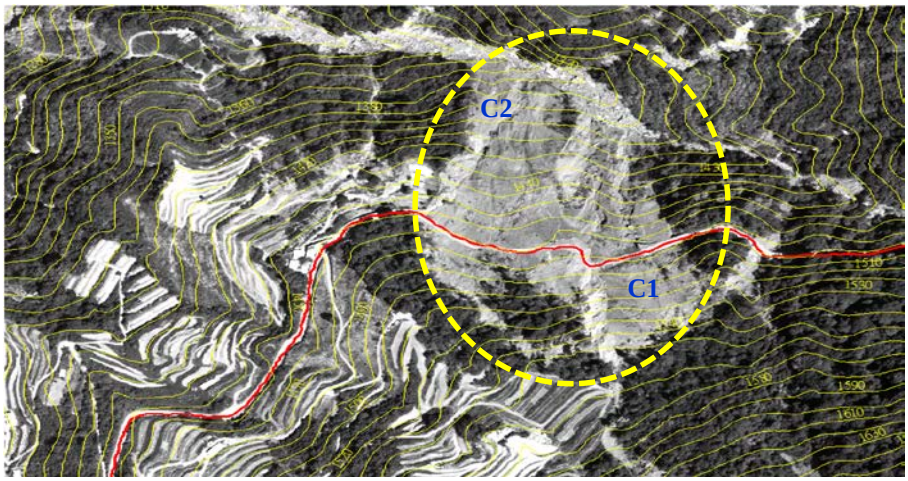

Figure 3 The topographic map, extended bare areas and road on September 6, 2009 [4]

4. Conclusion

The failed areas and rainfall data for 49K of Nantou 89th County Road are synthesized in this research. Based on this research, the critical rainfall boundary for the road at 49K is obtained as R=270 mm. If the average rainfall (I) exceeds 7.5mm and rainfall duration (T) above 40 hours, slope hazards may also happen. It is recommended to take the accumulated rainfall of 270mm as an indicator for a future evacuation.

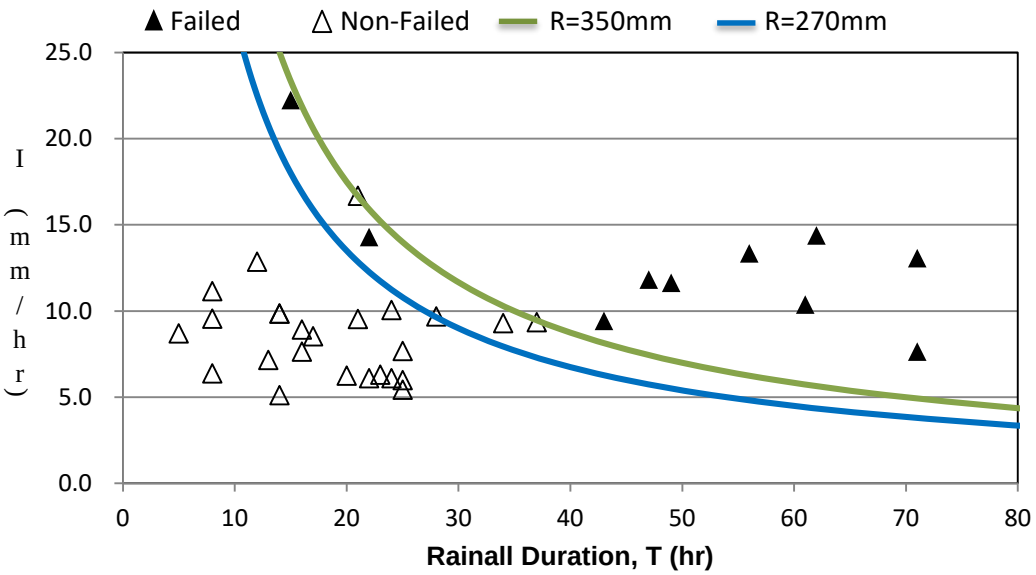

Figure 4 Average rainfall versus rainfall duration for cases at 49K.

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