Investigation and Studies of the Slopes along Chen-Yu-Lan River Watershed after Typhoon Morakot

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INTRODUCTION

The moderate Typhoon Morakot attacked Taiwan on Aug. 8th, 2009, and brought more than 2500mm of torrential rain in central and southern Taiwan. Slope failures due to rainfall conditions have been studied by many researchers and the impacts of unsaturated and saturated soil behavior on the slope stability are also considered in many papers. The objective of this paper is to investigate disasters that brought by the typhoon, and try to understand the failure processes and mechanisms of the slope failure of high terrace deposits in Nantou County during Typhoon Morakot.

STUDY AREA

Most of the occurred hazards during the typhoon in central Taiwan is in Nantou County. As shown in **Fig. 1**, Nantou County situates at the center of Taiwan. Most of the county is mountain areas. Thus, a lot of hazards, including flooding, slope failures, debris flow, and road and bridge failures have occurred in this county, especially inside Chen-Yu-Lan River Watershed, during Typhoon Morakot. There are 39 slope related failures occurred in this typhoon. Among these failures, 24 failures are related with failure from upslope and the others are due to the sliding from downslope.

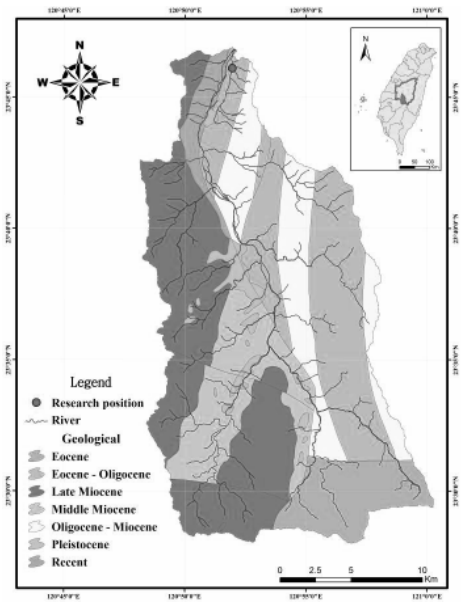

Fig. 1 Location and geology of Chen-Yu-Lan River Watershed in Taiwan

GEOLOGICAL CONDITIONS

There are three major faults, Dili, Chenyulan, and Shanshihchia Faults across Chen-Yu-Lan River watershed which causes the rock formation contains many fractures and discontinuities. Slates and meta-sandstones are the dominant lithologies in the metamorphic terrane. In the sedimentary terrane, sandstone and shale are the dominate rock formations.

INVESTIGATION AFTER THE TYPHOON

Investigation had been accomplished after the typhoon to document the location and extend of various types of failures. Thus, researches and analyses could be performed later on to reveal the causes of disasters. Several major types of disasters, i.e., landslide, debris flow, slope failure due to scouring, have been found during the in-situ investigation.

DISASTER TYPES AND REMEDIATION

There are 24 landslides related to the failure from the upslope of the road**.** The cause of the slope failure is mainly due to the infiltration of extreme rainfall within two to three days and rise of groundwater level. An example of a large landslide is shown in **Fig. 2**. The height and length of the landslide are around 450m and 950m, respectively. About the failure at the downslope of the road, the major cause of the slope failure could be due to the scouring by the flood or the attack by debris flow from elsewhere, e.g. from the opposite site of the river. An example of constructing temporary pass using cargo containers is shown in **Fig. 3**. A huge landslide had originated from the upslope due to the heavy rainfall, and caused the failure surface to extend below the road.

Fig. 2 A large landslide initiated from the upslope

Fig. 3 A temporary pass using containers is constructed after a large slope failure (Provided by Directorate General of Highways, Taiwan)

SLOPE STABILITY ANALYSIS

Infiltration analysis at each hour of rainfall is performed using SEEP/W. Then, the factor of safety of the slope using SLOPE/W can be calculated based on the result of infiltration. The slope may remain stable under the heavy rainfall condition if the river level is not going up. The factor of safety will reduce to 0.915 if the part of the slope below the river level is assumed to be eroded away by the flood. Thus, retrogressive slope failure will occur subsequently.

CONCLUSIONS

1. Locations of disaster were documented and type of failure was also studied.
2. There are 39 slope related failures at Taiwan- Provincial-Highway No.21: 24 failures are originated from the upslope of the road; and 12 failures are due to downslope failure.
3. The major cause of downslope failure is due to the toe erosion of the slope by the flood.
4. Cargo containers are used very often to construct a temporary pass effectively.
5. A long-span bridge is suggested and designed to serve as permanent remediation in order to avoid locations subjected to river scouring.
6. The factor of safety of a slope reduces as the river level rises.
7. The factor of safety can be reduced to 0.915 if the toe of the slope is eroded away due to the flood.
8. Retrogressive failure will occur if the toe of the slope is eroded away.

Keywords: Extreme Rainfall, Investigation, Slope, Disaster, Analysis, Infiltration