Assessment of Landslide Volume for Alishan Highway Based on Database of Rainfall-Induced Slope Failure

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Abstract—In this paper, a study of slope failures along the Alishan Highway is carried out. An innovative empirical model is developed based on 15-year records of rainfall-induced slope failures. The statistical models are intended for assessing the volume of landslide for slope failure along the Alishan Highway in the future. The rainfall data considered in the proposed models include the effective cumulative rainfall and the critical rainfall intensity. The effective cumulative rainfall is defined at the point when the curve of cumulative rainfall goes from steep to flat. Then, the rainfall thresholds of landslide are established for assessing the volume of landslide and issuing warning and/or closure for the Alishan Highway during a future extreme rainfall. Slope failures during Typhoon Saola in 2012 demonstrate that the new empirical model is effective and applicable to other cases with similar rainfall conditions.

Keywords—Slope failure, landslide, volume, model, rainfall thresholds.

I. INTRODUCTION

In Taiwan, two-thirds of the total land area is in the hill area and other in the plains. Therefore, the hill areas have to be developed and utilized when the plains can no longer meet the demand of the population and the economic activities. Rapid development of the communities in the hill areas has increased the impact of landslides, in terms of loss of properties and lives, in these areas. Taiwan is located at the collided subduction zone of the Philippine Sea Plate and the Eurasian plate, which results in many folds and faults in the formed mountains. Taiwan is also located in the western North Pacific typhoon belt. Due to a number of reasons such as typhoons, storms, rainy season, weakness of ecological environmental, and hillside development, the landslides and debris flows often occur, which cause the blockage of roadways, isolation of the mountain areas, and loss of properties and lives.

The disaster prevention along roadways in the hills areas should first rely on warning and prevention. To enhance the landslide volume of the highway slope-failure assessments system, a variety of factors should be considered and their impacts should be studied. In Taiwan, considering that rainfall is one of the direct causes of slope failure in the hills areas, the rainfall is selected as the basis for the proposed models in this paper.

Here, the slopes along the most important access roadway from the plains to the mountain of Chiayi area, namely, the Alishan Highway (Tai-18), are examined. In this study, the empirical models of landslide volume are established based on a database of slope failures along Tai-18, caused by heavy rainfall, over a period of 15 years. The results provide the prediction formulas for calculating the landslide volume for hazard managing Tai-18.

II. REVIEWS

A. Relations between Slope Failure and Rainfall

Slope failure is triggered by both earthquake and rainfall in Taiwan. For the rainfall-induced slope failures, a threshold is defined as the rainfall beyond which slope failure can be triggered. The rainfall threshold models may be physical-based [1]-[4] or empirical-based. The empirical-based rainfall threshold model is usually established by taking the lower bound of the rainfall conditions, such as rainfall intensity [5]-[8], rainfall duration [9], [10], [8], cumulative rainfall [11], [12], or antecedent rainfall [13], [14] that can cause slope failure.

B. Exact Time of Slope Failure

Ikeya (1983) [15] pointed out in a torrential rain that caused sediment disasters, the typical relationship between rainfall duration and cumulative rainfall is like the one shown in Fig. 1. First, there is some light rain at the beginning of the rainfall period. Then, the rainfall intensity starts to increase more rapidly. After a continuous rapid rainfall period and cumulative rainfall, the sediment disasters occur when the rainfall intensity decreases and the gradient of the cumulative rainfall curve become smaller. The data of slope failures along the Alishan Highway were collected and summarized over the past 15 years by the Alishan Public Works Section of the Fifth District Maintenance Office, Directorate General of Highways, Ministry of Transportation and Communication, Taiwan. At each occurrence of slope failure, the staff of Public Works Section measured the avalanche size and took photos as records shortly after the slope failure and definitely before the site clean-up. These records, including location and the volume of slope failure, are generally very accurate except the exact time of occurrence. In this paper, the records of landslides and slope