



Hazard analysis of the Li-shan landslide in Taiwan

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Located at the midway of the east-west cross-island highway (the highway 8), Li-shan is an important small town in central Taiwan. In mid April 1990, due to heavy rain, the site near the junction of highway 7A (73k+150) and highway 8 (82k) began to subside as its foundation are located at one of the sliding blocks of this landslide. It is generally suggested that the Li-shan is located at a colluvial formations originally from the Miocene Lushan slate formation. This landslide is predominantly caused by heavy rain together with poor drainage condition.

In order to keep the highway functioning and secure the town for living, the government had executed the remediation treatments since July 1990. A dewatering system comprising surface ditches, drainage wells and two drainage galleries, was constructed and completed in early 2004. And the effectiveness of the remediation treatment has been strongly revealed as the Li-shan landslide survived the Chi-Chi earthquake ($M_L=7.3$) in 1999 and the severe typhoon caused flooding in 2004.

In view of the complicated characteristics of the sliding area, it is of great interest to understand to the failure mechanism. In this study, topography, geology, and ground-water condition of this area were first studied with field investigations. A series of

limit equilibrium back analyses were performed to understand the failure mechanism of this landslide for different phases. In addition, considering the spatial uncertainty of the parameters, hazard of the treated residual slope was estimated by the Monte Carlo type of analyses.

Stability back analyses were employed to study the behavior of slopes in the Li-shan landslide. The slopes are quite stable for dry condition, but become critical for fully saturated condition. The remediation treatment is essential as the precipitation in this area is quite high in this area. In this study, coupling GIS with a program written in Visual Basic, together with an interface written in JAVA to more efficiently control the limit equilibrium analysis PC-STABL6 model, a probabilistic hazard analysis method has been established for spatially analyze the hazard of a landslide area. And this method was applied to estimate the hazard of Li-shan landslide area.

Through a series of analyses, the hazards of sliding bodies as well as sliding areas are evaluated. It shows the influence of groundwater level is significant, which reveals the importance of groundwater control and monitoring. The results also show that the safety of northeast area and southeast area are significantly improved as the groundwater levels are lowered by drainage wells. However, it is comparatively dangerous for the west area, which has been supported by further development of surface cracks.

Impact of earthquake, heavy rain, as well as time effect is important for a more practical hazard estimation and worthy for further implementation. The results show the improvement in terms of the change of probability is not so significant. This could be caused by different uncertainty levels in input variables and inter-dependency of the variables, which are essential issues to be considered for further development of the probabilistic analysis model. As drillings in the west and northeast areas are not sufficient, the three-dimensional elevation model cannot accurately obtained by the GIS. More drillings in those areas are necessary in the future.